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CONTENTS

JOURNAL
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THE DEVELOPMENT AND USE OF STEREO PHOTOGRAPHY FOR EDUCATIONAL PURPOSES*

C. KENNEDY**

***Summary.**—Investigating the possibilities of stereo photography in connection with the study of art and other subjects in schools and colleges, the various properties and the historical development of stereo are analyzed, and the significance of the outstanding steps in the development pointed out.*

After reviewing the theoretical conditions for accurate reconstruction of the binocular visual image, the practicability of the system using polarized anaglyphs is demonstrated and the advantages of stereo and its probable use in education discussed.

The conclusions here presented embody the first results of an investigation along practical lines made at the instance of the Carnegie Corporation and forming a part of the Corporation's carefully considered program to stimulate and improve education in the fine arts. The writer was chosen to guide this particular project in its initial stages for the reason that, over a considerable number of years, in connection with research in the field of Italian sculpture at Smith College and under the auspices of that College in Italy, he had had the most exacting practical experience in the photography of objects of art, and had been active in the publication of these studies in a series of volumes illustrated by actual photographic prints.

The problem in the form in which it was presented may be stated simply: sculpture is a three-dimensional art; for years, in fact since the earliest days of photography, the effective way in which the third dimension is reproduced by stereo photography has been emphasized in theory and, under various conditions, proved in practice; why, then, is its use for serious study in our colleges and secondary schools practically non-existent? After a period of the most exaggerated popular enthusiasm for its miracle-working properties, an enthusiasm that reached its height not far from a century ago, the stereo viewer, with its battery of warped cardboard stereograms, has been laid upon the shelf. Every attempt to revive it in a different

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*Presented at the Fall, 1935, Meeting at Washington, D. C.

**Smith College, Northampton, Mass.

form has been heralded by the Press as the promise of a new wonder of the age, but, from the point of view of general interest, has failed of its mark. Even very real steps in advance have been turned to account only for technical side issues, such as surveying, or have become the hobby of a somewhat fanatical brotherhood of camera owners who have, in their enthusiasm, gone even as far as to publish their own periodical, but have never succeeded in establishing stereo photography as a normal and basic means of presenting visual truth. Recent technical literature is full of mournful allusions to the beauties of stereoscopy, and the assertion that there is no sensible explanation of its failure to find its proper recognition. Yet one can not possibly postulate apathy upon the part of the public: if we may take the newspapers as an indication of the attitude of the masses we can discern in their policy so tense an expectation that stereo is to be the new order of things that they rush into print with the wildest schemes of the crank inventor. Recognizing this, the Carnegie Corporation had reason to hope that the trouble lay only in the fact that the public had not been given solid enough food—that they had outgrown their wonder at viewing a child with a doll through an antimacassar, and even the Obelisk of Luxor—and it was the writer's job to make new stereograms providing material for more serious pursuits—for the study of the sculptures of Donatello and of Michelangelo. It was in trying to do this that I became aware of factors that provided, I believe, a more fundamental explanation of the situation, and gave me faith in the importance of stereo in the future.

These factors may be summarized under two headings, of one of which we are acutely aware. This is the unsocial character of all practical stereo viewing to date: it has remained, in a sense, a laboratory phenomenon, because only one person at a time can see a given view; and even he must, for that moment, submit to being cut off from the outside world while he holds his eyes stationary before a piece of unfamiliar apparatus. Though that is probably the chief reason why stereo has remained a thing apart, it is doubtful whether it can alone account for the apathy of the serious student in fields such as the writer's. To explain such apathy we must first postulate a property of the intelligence that shows not in conscious theories but in conduct. Apathy, dissatisfaction, or an unreasoning aversion may be the result of an unanalytic recognition of positive faults or even of the lack of something essential, though the individual may be quite unaware of the nature or the cause of his reactions. My own contribution to the photography of sculpture has been to insist upon qualities that, it is supposed, the average person can not appreciate; yet in this work the public has invariably responded to them quite spontaneously once such results had been achieved. Faults of a secondary order exist in all systems of stereo customarily used, and personally the writer is convinced that they have been responsible for more trouble than the small actual differences between right and wrong would indicate.

It is not proposed to review again the history of stereo, but it may help to bear in mind the fundamental problem in its simplest form, and to point out the relation between the various attempted solutions. Fundamentally it is this: we must procure two pictures corresponding respectively to the images that the two eyes receive when performing their normal functions under the given conditions; we must then place the two pictures before the observer in such a way that each eye again functions normally when presented with its proper view. Ideally, the eyes should be unable to distinguish the views from the images they would receive from the object itself under these same conditions. It is true that the most fantastic proposals purporting to disclose a short-cut to three-dimensional photography are repeatedly made by persons who claim that by chance or ingenuity they can produce a stereoscopic effect—note the word effect—without taking two pictures and particularly without providing adequate means whereby each eye sees its proper image. Thus, they either ignore or vainly hope to dispense with these requirements, which H. E. Ives has recently defined as the axioms of stereo photography—"vainly," because when the observer looks at the three-dimensional world about him, the images formed upon the retina of his left and his right eye, respectively, are alike only in one respect, and that is philosophically, or conceptually; in plainer language, they are images of the same subject. In every other respect—from the point of view of geometry, of measurement, and of color—the left and right eye images that we so carelessly regard as almost the same are actually completely different. The distances between the trees, the shapes of the stones, the colors of the leaves are distinctly and measurably different. One of the most amazing of human faculties is the ability of the mind to unite the flat images upon the left and the right retinas into a three-dimensional composite that seems to have existence in space. Every serious proposal, the record of which has figured in the history of stereoscopy, has admitted the necessity for the two images, and inventive energy has expended its force almost exclusively upon devising methods of presenting them separately to the proper eyes. If one may imagine the two photographs to be the size of the object itself, he can see that they will occupy their proper positions in relation to the eye only if they are superposed; and if the size be decreased they will still overlap and must be separated. Whether this be done by crossing the axes of vision before reaching the pictures, placed, in this case, in reverse order side by side, as Eliot proposed; or by mirrors, as Wheatstone first suggested; or by prisms, or lenses used in such a way as to take advantage of their prismatic effect when viewed off axis, as they were in the popular Brewster stereoscope, the parent of most of those in use today; or by making the positives so small that when viewed through lenses even without prisms they may stand unreversed side by side, as they do in von Rohr's *doppel-verant;* or by transforming them into color anaglyphs—in all these we may recognize the preoccupation of the inventor with the problem of providing for the proper disposition of the two photographs.

Accepting, then, the principle that we must start with two disparate images, there was first the problem of choosing the most promising of the various methods of separating the images and presenting each to the proper eye. It seemed reasonable to explore especially the methods that gave some hope of a really social procedure, which did not involve a temporary separation of the observer from his fellows. They are few; they reduce, in fact, to two: upon the one hand, those depending upon a critical angle of view, a device that was used by Eliot in a crude form and which is much better provided for in the parallax stereoscope suggested by Ives; and upon the other hand, those that make use of anaglyphs. In the parallax stereoscope, as in all the simple forms of apparatus depending upon a critical angle of view, the possible shift of the point of observation is limited to one-half the interocular distance, or somewhat less than 35 millimeters, so that we probably should not have thought of it as capable of a wider application had it not been for the amazingly complete survey of the possibilities of the system by Dr. Ives, a survey of which the parallax panoramagram now successfully used in advertising is an important by-product. It is the only system that asks nothing of the observer, and, the writer believes, will have its applications also in education. Dr. Ives has, however, pointed out its ultimate limitations, which, in the narrower field of this study, are serious.

In the past, anaglyphs have been limited, for practical purposes, to the use of red and green glasses with correspondingly colored images. It might be possible, and has probably already been proposed, to select other colors which would at the same time give a more pleasant looking image and reduce the faults arising from color rivalry, of which more will be said later; but at the present moment in the history of the industry any method of separating the images by color is ruled out by the simple fact that it could not be used with color photography when we get it. It was very fortunate, then, that at this critical moment, the invention of sheet polarizer made possible upon a practical scale the differentiation of the images by polarized light, a method that has long been proposed, and has even been tried upon an experimental scale, in so far as that was possible, with a Nicol prism by Anderton as early as 1893. The problem that seemed so hopeless in the first months of the present investigation could, with the use of this material, be approached in the most straightforward way.

What were the questions that remained, after this solution for the basic problem was accepted? It will be seen that, while those responsible for the progress of stereo to date had been in agreement upon essentials, they had differed in respect to the convenience or practicability of the methods they proposed, and in the extent to which they provided, or failed to provide, for the fulfillment of the other conditions implicit in our statement of the problem. Sometimes the limitations seem purely arbitrary. Practically all the cameras built for stereo have the disadvantage, serious for the author's work, that as we try to photograph nearer and nearer objects the images of the objects go farther and farther off the plate. Obviously, this condition can easily be rectified by giving up the attempt to keep the axes of the two lenses parallel and by turning the cameras as the eye would turn. In other cases the limitations are inherent in the method. Often they are not serious. For example, some systems of stereo viewing have not been used as commonly as they might otherwise have been because they require two prints large enough to be properly viewed at a distance great enough for the eye unaided by lenses to focus upon them. Such is the case with the Wheatstone stereoscope, using mirrors, which, in its simpler forms, requires also the reversal of one or both the prints. While this has apparently militated against the popularity that the device might otherwise have been expected to have had, the instrument has found its proper uses in the experimental laboratory where it has been extensively employed, especially for the study of the physiological properties of the eye. Many methods, taking advantage of the commonly accepted theory that the proper exercise of the physical functions of convergence and accommodation is not a necessary condition of reasonable viewing, fail to provide for one or the other or both. Viewing two transposed pictures set side by side by crossing the axes of vision before reaching the plane of the pictures obviously gives a convergence that is always exaggeratedly more than what would ordinarily accompany the accommodation of the lenses of the eyes looking at the plane; and since this situation is so extreme, there is usually no attempt when using the method to match either convergence or accommodation to the original experience of the observer when viewing the object. Very few of the lens stereoscopes are built with a view to reproducing the conditions of convergence and accommodation; the common type seems rather to have been constructed on the theory that the most restful position of the eyes, and therefore (though this does not make sense) the desirable one, is when set for near infinity. Moreover, prisms, in most of the forms in which they are used, give distortions that we must assume in general are ignored.

How are we to find our way among the mass of variant interpretations of the meaning of refinements in stereoscopic presentation? All these methods, as contrasted with purely visionary ones, work; and if they worked well enough we could learn from them how to proceed in our attempt to solve the purely social aspects of the problem. But, as used, they are not without annoying defects. In varying ways and in varying combinations the minor factors that they disregard take their revenge. Though my eye muscles are practiced in acrobatics, and I can get beautiful clear images by crossing my gaze to view transposed pictures, in a few moments I am aware of a painful eye-strain; and wherever a separation between the normal convergence and accommodation occurs, this strain develops in a proportionate degree. The muscles that control the two functions are accustomed to working in unison, and although they can be trained to operate simultaneously for different distances, discomfort, if not pain, results.

Eye-strain of a different kind, which no amount of practice will reduce, comes from the struggle and uncertainty to which the two eyes must submit in attempting to fuse two-color anaglyphs. In viewing red and green images through corresponding glasses the eye is presented with two forces working against each other. The forms, which we shall assume are correct, are working for fusion; the colors are working for disassociation. In passages where form predominates, as in aerial views filled with minute detail, it will win, and few persons will have difficulty in achieving the three-dimensional sensation. Where larger areas of unbroken color exist, as they frequently would in colored anaglyphs of photographs of sculptured surfaces or objects seen against a plain background, the red area would struggle against uniting with the green area, and strain would result.

Methods that rely upon attention to fix the gaze of the observer upon the right one of two pictures make no provision for obliterating from the field the picture that is not wanted; and it remains, a disturbing image of full intensity having a ghostly existence, flat, to either side of the desired image in three dimensions.

Another series of annoying phenomena are distortions resulting from the neglect to take into account all the factors involved in the reproduction of normal viewing conditions. These have been more studied of late and it has been pointed out that many of them could be eliminated by modifications of existing apparatus. The most usual cause of exaggeration of depth is the intentional use in stereo cameras of an interlens distance larger than that of the average interocular. The public is supposed to like it. I could not find, in New York, a stereo camera that could be adjusted even to my own interocular of 62.5 millimeters. The other most common cause of depth disturbance is the failure to fulfill the requirements of a proper optical system for the lens viewer. It is here that much work has been done, though still more needs to be accomplished. The basic rule, as it is usually put, is that the focal length of the taking lens should be matched by that of the viewing lens. The real difficulty results from the change in effective focal length of lenses used on a focusing camera; the remedy most recently advocated compensates for the trouble instead of eliminating it, and only under certain conditions is this advisable.

Eye-strain and depth distortion are merely the two obvious troubles caused by defective systems. There are others—for example, the curious appearance that objects have of dropping back into successive planes instead of rounding plastically. There are indications that this may be due fundamentally to the failure in stereo still cameras to turn the plate, or, in a more practical sense, each half of the camera to correspond with the changing convergence of the eye. The theory must be that they are designed to work for infinity, defined in terms of clarity of focus, but stereo vision is very sensitive to changes in convergence on objects much more distant than those in the nearest limits of the depth of field of a lens of the short focal length used when the two pictures are taken side by side upon the same plate. Any views not taken with the proper system, even those of subjects other than sculpture, made with a camera of the accepted type, will show this defect; with time, one becomes acutely aware of it. The same effect results from quite different causes: bad definition due to a poor projecting lens, or coarse grain either in the lantern slide or in the screen, will destroy or disturb the accurate register of the smaller disparities upon which our stereoscopic sense of the rounding of a surface depends; and again the three-dimensional character of the subject is reduced to a series of receding planes.

There remains a category of trouble that does not show in deformations of the stereoscopic views, but makes itself felt by retarding the action of the eyes in achieving fusion. In the earlier phases of this work it was quite customary for the observer to whom the views were being shown to shout, excitedly, "Oh! now I've got it!" When, as time went on, following the indications of theory, improvements in quality were introduced by converging the cameras, using larger negatives, reducing screen grain, and projecting through lenses with better definition, even when the differences were so slight that they seemed imaginary, the immediacy and ease with which the observer saw the three-dimensional image increased by geometrical progression. In the demonstration accompanying this paper, if one has difficulty in looking at the images upon the screen, either the lack of sufficient illumination, due to the fact that the design of lantern slide projectors has lagged so far behind that of motion picture projectors, must be blamed, or the rough surface of the screen. Also it should be remembered that one person in ten may be expected not to have normal stereoscopic vision, and an observer who does not customarily coördinate the use of his two eyes will see no better, but, if the report of those who have tried it may be trusted, at least no worse than he usually does. Moreover, the ocular parallax that produces stereoscopic vision is effective only in the direction of the separation of the eyes; if the head is inclined when viewing photographs that were taken with the camera on its normal horizontal bed, the effectiveness of the disparities will be diminished. The spectacles are so made as to discourage this.*

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*Spectacles equipped with polarizing material[1] corresponding to polarizers in the stereo head of a lantern slide projector were supplied to the audience, with which to view the stereograms projected upon the screen.

Judging, then, from the contradictions and inaccuracies in the experimental data that had accumulated in the past, we might say that at the outset of this investigation, although we knew the minimum requirements, we could not trust, without testing them further, theories that this or that additional factor was negligible; the results of accepted methods have not been good enough to warrant admitting the assumptions upon which they were based. Moreover, experiments had been difficult to perform. One of the great beauties of the new polarizer used in this system was that it made possible not only one but several new methods of viewing stereoscopic photographs which, between them, permitted the greatest freedom and flexibility of experimentation. The writer has, moreover, been fortunate in having been able to avail himself of the technical advice of the inventor, Mr. Land, and of his associate, Mr. Wheelwright, who have followed the successive stages of the development of the project with the closest attention.

At the outset, it was decided that the best way of finding what a good stereo reproduction looked like was to reproduce faithfully, and, wherever it was possible, in the minutest detail, the physical experience of vision. If I were asked what were the conditions for perfect stereo viewing I should not, at this moment, relax any of these precautions. Since this is, in a sense, the crucial question, we should perhaps analyze the situation implied by such a statement. For perfect viewing, or for orthostereoscopy, one should have two cameras or their equivalent; toed in for any given picture to the angle of convergence of the eyes; pivoting about an axis corresponding to the axis of rotation of the eye-balls, and, like that axis, the distance of the radius of the eye-ball behind the forward nodal point of each lens; and separated by the observer's interocular distance. The pictures should then be seen at actual size, normal to the axis of vision, and points on a vertical line through the intersection of the axes of vision must be superposed. For perfect results the observer can be in only one spot, exactly in front of the point upon which his attention was fastened (and hence upon which the cameras were focused, a point that would normally be the middle of the picture) and at the distance equal to that of the forward nodal point of the taking lenses from this point of the object. His convergence and accommodation then are matched and reduplicate those he would have used when looking at the object from the position of the camera. Even these highly specialized conditions can be achieved with the apparatus now available, and even if it be not necessary to insist upon such perfection for practical purposes, it is highly desirable to be able at any time to refer to it as a standard of excellence.

How far may we safely relax these restrictions in order to adapt the procedure to larger groups? That question the present demonstration will answer. As it is now set, the projector marks the line back of which it would be undesirable to be seated for a projected picture of the size upon the screen.* If the audience were larger it would be necessary merely to increase the size of the picture proportionately. The desirable size, then, as computed for these pictures is approximately what one would normally use. We accept without much question distortion of one kind or another in motion pictures as now shown. Von Rohr has pointed out that because the perspective of any given view was a function of the distance of the camera from the object at the time, there is only one spot, at any moment in the course of the changing conditions that the reel produces, from which the image upon the screen can look right. Furthermore, in far too many theaters the angle of projection is extreme, and although, if the throw is long enough, the focus at top and bottom is passable, the enlargement of the picture as one looks toward the bottom is pronounced. In most theaters, too, the entire screen is above the audience, so that the angle of view produces distortion even from the central seats, not to speak of the recognized distortions from the side. Stereo views are subject in much the same way to exactly the same destructive forces and there is no theoretical reason why the results should be worse. This audience has undoubtedly been looking for distortions, and has seen them. The public, too, may be more aware of them at first, because of the novelty of the medium; then, as in the case of flat photography, they may end by ignoring them. It is possible that, because stereo is so much more completely a reproduction of reality, it may be more difficult to make such allowances as we are accustomed to make for photographs and paintings, which are more obviously conventions. In presenting stereo to public audiences it would seem, therefore, a sound policy to avoid at least all causes of distortion that are unnecessary, such as the exaggerated interocular distance in the taking cameras. Those who have interoculars representing departures one way or the other from the average will, in general, have to suffer for it, although, if they were fussy, wide-

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*About 6 by 8 feet.

eyed people could compensate for the difference to a considerable extent by sitting farther back and narrow-headed people by taking seats in front. The size of the picture should be figured, in relation to the average focal length of the taking camera, for the distance to a point somewhat nearer the front than the middle of the block of seats. The larger the picture and the greater its distance, the more persons could see it with the minimum distortion of depth as well as of the other two dimensions. Gigantism is no more to be feared, and no less, than in the two-dimensional cinema. Stereo, in fact, provides the only means of controlling scale, but this can be done under theater conditions only at the expense of comfort. Care must be taken not to permit a careless operator to separate the pictures by more than interocular distance, for he might make the audience even sea-sick; but a shift in the direction of convergence, if slight, would by most persons be followed without great discomfort; and close-ups, which should look smaller, would appear better if so treated. Registration would have to be exact, for a vertical shift in either picture as compared with the other would make fusion difficult and unstable and produce strain.

The next question that will undoubtedly be raised is, "How complicated is the apparatus that would be required?" The reply that is most directly to the point is that the stereograms being shown in this demonstration are being projected from single lantern slides of regulation size by a single 500-watt projector of the usual type, burning, for the moment, an over-voltaged 1000-watt motion picture projection bulb and equipped in front of the lens with a stereo head, about 4 inches cube, containing the two polarizers corresponding to your spectacles. The images, as may have been noticed, may separately be slid at will to the side to provide for changes in convergence, or up and and down to correct any vertical shift that may by chance be present. The double camera with which the sculptures were photographed had an interlocking converging and focusing device so that convergence automatically followed focus. A still simpler camera is now being designed, on the model of the projector. As regards the feasibility of using similar apparatus for the motion picture, obviously the distinction is not a fundamental one. Whatever we have learned from the work already done holds equally true for motion pictures: the greater refinement of the equipment should lead to pictures of even better quality than these.

What does one gain by the use of stereo? This question should be put with the utmost seriousness at this time. The age-old problem of presentation is so nearly solved that before we embark upon an attempt to arrange the practical details of its use in various fields we should stop to make sure what it is we expect from it. When the Carnegie Corporation asked the writer to investigate for them the possibilities of the use of stereo in the schools and colleges, this undoubtedly was the result of a purely spontaneous idea that occurred to somebody in a quite unassuming way, but there is every evidence that such an idea did not occur to them alone. From all sides there is a sudden and incomprehensible interest in stereo, even before color is developed to the point where we know exactly how to proceed with that newest of all conquests of the reproduction of the visual world.

To the average person, stereo is synonymous with the third dimension. We must not forget that there are factors other than stereo from which we get the effect of depth even in a single image upon the screen—overlap, the shape of contours, the shape and position of reflections, light, shade, cast shadow and reflected light, atmospheric effects, depth of focus, and the relative apparent movements of objects when they or the camera is in motion. It is a cumulative body of effects that build up, even without binocular vision, a strong sensation of depth, and are important in adding to its poignancy when a picture is seen stereoscopically. But the stereoscopic sensation of depth is something of a different order, which can best be described by the word "reality," and there can be no hesitation in accepting the popular verdict that that is its most striking aspect. Most persons do not realize that binocular vision has other important implications that improve even the photograph of an object that does not have three dimensions. They would unquestionably believe me a quack if they heard the report that I proposed to photograph paintings with this system, or they would assume that I expected in that way to infuse them with a false stereoscopic depth. But there is another property of binocular vision that is even more exciting at the present moment because it has a direct application to color. It results from the principle that in specular reflection the angle of incidence is equal to the angle of reflection. For a given light-source the direction of the surface of the object that would fulfill this condition must be different for each eye, to an extent that increases as the eyes, always a constant distance apart, approach nearer the object. Thus, the bright spot that appears in one position upon the object for the left eye will be seen in a different place by the right eye—displaced, that is, in a way determined by the shape of the contiguous surface. To put it in another way, the same unit of surface will appear bright for one eye and darker for the other. This type of retinal disparity is the most powerful phenomenon that gives meaning to reflection, or sheen or luster, which in flat photographs has been the bane of the photographer. For the first time we have been able to make a bronze figure look like bronze; one can see even that the surface has been waxed!

The significance this has for color is not self-evident, but those who have been confronted with new color processes challenging the understanding and have looked at natural objects repeatedly through a spectroscopic analyzer, will already be aware of the amazing extent to which even the surfaces that we think of as matte are reflecting, with its color unchanged, the light that falls upon them. You have also had evidence of this in the films prepared by Mr. J. W. McFarlane,[2] in which either wholly or partly, as the case may be, these reflections have been removed with a polarizing sheet. In this, as in other physical sensations, we are not given to analyzing our impressions; we are none the less aware of any failure in reproducing them. The difference may be illustrated by describing an experience in making a Dufay stereo color picture on two 5 × 7-inch films. I was photographing a bronze head of Paul Robeson, by Epstein, and my first shock came when I had to remove the bronze from a room with a window opening out upon a lawn because of the vivid green reflections from the grass all over the bronze. A room with gray burlap walls proved a suitable place, but the two positives were very disappointing. I blamed the film especially for its failure to record the black of the polished marble base—it was a dirty gray. Discouraged, I had little will to make the effort to arrange the films so that they could be viewed in stereo, but, to my amazement, when I did, the base went black! Then only did I realize how much reflected gray light had been coming from it, which, in the single print mingled with the black and became a part of it, but which, in the stereo, was recognized as a mere reflection, and, in a sense, disregarded, as in life.

It follows that, even when we succeed in obtaining films that will truthfully reproduce the colors of nature, they will not *seem* true until we add binocular vision. Meanwhile, even imperfect color looks far more reasonable in stereo. Pictures with gold backgrounds have been the despair of critics who must lecture with an image upon the screen, and even the yellow of the best color photograph is pasty looking; but in these pictures we have gold! Experiments made with paintings in tempera, and especially with those painted in oil, with luminous glazes by the great Venetian masters, would indicate that this phenomenon is still an important one in its less spectacular forms. The future of stereo in the educational field is clear, then. It will be invaluable in art, in botany, geology, mineralogy, in experimental psychology, in medical schools, and wherever accurate reproduction of the visual image is an axiomatic need. Furthermore, in this educational program the motion picture will have an undeniable place.

(During the presentation of Professor Kennedy's paper, spectacles fitted with polarizing filters were supplied to the audience, with which to view the polarized anaglyphs projected upon an aluminum screen by means of a lantern slide projector. More than 150 such spectacles were distributed among the audience and a large number of views of objects of art, sculpture, etc., and outdoor scenes were seen in stereoscopic relief.)

REFERENCES

[1] TUTTLE, F., AND MCFARLANE, J. W.: "Introduction to the Photographic Possibilities of Polarized Light," *J. Soc. Mot. Pict. Eng.*, **XXV** (July, 1935), No. 1, p. 69.

[2] MCFARLANE, J. W.: "Demonstration of Photography by Polarized Light," presented at the Fall, 1935, Meeting at Washington, D. C.; to be published in a forthcoming issue of the JOURNAL.

DISCUSSION

MR. RICHARDSON: You said that the color would be different with reflected light. Exactly what, with two-eyed vision, would be different?

MR. KENNEDY: In a single flat photograph the observer can not separate the color of the reflected light from the basic color. Consequently, we accept the *mixture* as the basic color, and the mixed color looks wrong. When we look at the object itself we are able, in a sense, to disregard the color that we recognize as that of the reflected light, and look through it, as it were, to the actual color of the surface.

From the disparities in a stereogram we know which is the reflected color. We have only to remember the appearance of the best color photograph of gold or bronze, which are obvious and exaggerated examples of a lustrous material, to realize that a color film of a painting can never reproduce the effect even of an oil glaze unless the binocular phenomenon is taken into consideration.

MR. GAGE: I once took two pictures of a single object with the same camera from points about twenty feet apart. I was able to arrange the prints so that a railroad trestle about a mile away stood out with annoying prominence. It seems to me when taking pictures of mountain scenery, it might be desirable to separate the eyes by an exaggerated distance, and, whether the effect of depth could be exaggerated or not, I believe the result would be very interesting.

During the demonstration here, I was noticing the effect that resulted when only one eye was used and the polarizer rotated. With a few of the pictures, when they were very nearly in register, rotating the polarizing plate gave the appearance of rotating the object somewhat.

MR. KENNEDY: If you are interested in "tricks," we have many of them. For instance, I can determine with accuracy about what axis the apparent movement of the three-dimensional image will pivot if, using both eyes, you move from side to side across the room. Provided your eyes are acrobatic enough to follow, I can also make the image come out into the room to meet you: it would then appear not only to exist in space a very short distance from you, but it would appear smaller as well. In comparison, a flat image of the same size and upon the same screen would look ever so much larger and farther off.

MR. SHEA: How nearly equal in intensity must the illuminations received by the two eyes be? How nearly equal were they here? I was under the impression that there was a difference in intensity, and it detracted somewhat from the contrast that might have been present had the intensities been equal.

MR. KENNEDY: In the camera that I used for many of these pictures I used lenses that were taken from an old stereo camera, and I found after making a number of exposures that the apertures were not precisely matched. The negatives were given the same development, and I had to compensate for the difference in density by a difference in printing time; obviously a correction of that kind can at best be approximate.

MR. SHEA: In some of the last pictures shown I think the correction was completely made.

MR. KENNEDY: The degree to which it was successful was simply a question of the skill of the printer. Of course, except for differences in the intensity of reflected lights, the two images should be of the same density, and would be when using a properly constructed camera.

MR. JOY: In some colored pictures, there appears to be so much contrast between the colors that they seem too artificial. If depth were added to the picture in the manner here demonstrated, would it tend to tone down such contrast and make the colors appear more normal with respect to each other and the rest of the picture?

MR. KENNEDY: The only effect stereoscopic reproduction has upon color is that of which I have already spoken. In some cases a better balance might result between the colors, because some of the defects you describe might well be explained by our failure to distinguish reflected lights from local color, especially since the two would often be in a different key.

MR. CRABTREE: In commercial use would it be necessary to sterilize the spectacles after each performance?

MR. KENNEDY: The glasses are water-proof and could be dipped into an antiseptic.

REPORT OF THE STANDARDS COMMITTEE*

The recent misunderstanding concerning the 16-mm. sound-film standards has emphasized the need for close coöperation with other standardizing bodies, especially those in Europe. Various proposals to that end have been made, among which were:

(*1*) That the Engineering Vice-President be requested to appoint several European members of the SMPE to the Standards Committee, in order that they may establish a direct liaison between this Committee and the European Committees.

(*2*) That copies of minutes of the meetings of this Committee be sent not only to such foreign members, but also to the secretaries of other Societies interested in motion picture technology and standardization both here and abroad, and to a selected list of persons who might be expected to offer criticisms or suggestions.

Thus the other standardizing groups would be acquainted with the plans and ideas of this Committee before they have become fully crystallized, and would have the advantage of discussing and comparing our plans with their own before taking final steps toward standardization. It is, furthermore, hoped that if this Committee takes the initiative, other groups will follow suit; and we may thus be able to consider their tentative standards before they have gone too far for reconsideration.

During his recent trip to Paris to discuss the 16-mm. sound-film standards, Mr. G. Friedl received a number of criticisms of our Standards Booklet which indicated that although the Booklet might be quite clear to American engineers, it could be made much clearer and more definite for those whose practices and languages differed to any extent. Mr. Friedl has gone over the Booklet in detail and has pointed out inconsistencies in the mode of presentation which the Committee will endeavor to clarify in the next publication.

The items under discussion at the present time are as follows:

Sprockets.—Sub-committees, appointed for the purpose, report that the manufacturers of camera and sound sprockets do not believe that these sprockets are as yet amenable to standardization. As most of the Committee was in agreement, the matter has been dropped.

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

Screen Brightness.—The general problem of screen brightness has long been before the Standards Committee. The excellent work of the Projection Screen Brightness Committee under the chairmanship of C. Tuttle makes it appear that a practical solution of the problem is in sight.

Photoelectric Cell Specifications.—The specifications proposed by the British Standards Institution for photoelectric cells are under consideration by the Sound Committee, and we are awaiting their report.

8-Mm. Sound Film.—Dimensional specifications have been submitted for the standardization of 8-mm. sound film. Since, apparently, no such film has yet been produced commercially, it seems too early to attempt standardization. It is felt, however, that the time to begin work on standards is before too many different forms of apparatus appear upon the market.

16-Mm. Sound Test-Film.—The production of a 16-mm. sound test-film, similar to the SMPE standard 35-mm. sound test film, is under way. The plan is to distort the frequency-volume curve of the negative so that the response curve of the positive will be nearly flat up to 5000 cycles.

2000-Ft. Reels.—The Standards Committee is preparing to act as soon as possible upon the recommendations of the Projection Practice and Exchange Practice Committees with regard to adopting the 2000-ft. reel proposed recently for positive film by the Academy of Motion Picture Arts and Sciences.

Standard Densities for Calibrating Sensitometric Instruments.—A request has been received from several of the laboratories that standard densities be made available for calibrating densitometers. A subcommittee is investigating this problem.

16-Mm. Sound Lead.—The German standard for the lead of the sound over the picture in 16-mm. sound film is 27 frames. The SMPE standard is 25 frames. A compromise proposal of 26 frames was made at the Paris Congress in July. The Standards Committee is at present in favor of agreeing to the proposal and changing the SMPE standard to 26 frames, but it was deemed advisable first to consult the various equipment and film manufacturers before formally adopting the change.

Definition of Safety Film.—A sub-committee is being appointed for the purpose of looking into the specifications of safety film stock, and the desirability of changing our definition to agree with that proposed at the International Film Congress.

E. K. CARVER, *Chairman*
J. A. DUBRAY, *Vice-Chairman*

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DISCUSSION

MR. MITCHELL: What, if anything, is being done about adopting the standard 35-mm. positive perforations universally? It is necessary again to call attention to the problem of printing positive stock from a negative, the perforation height of which differs by 0.005 inch. The matter has been called to our attention periodically, and it is almost impossible to get the high-quality result we require today unless it is straightened out. I suggest that further consideration be given to the possibility of using positive film having the same height of perforation as the negative. I am sure you will find that such film can be used in existing projectors satisfactorily.

MR. CARVER: Do I understand that you recommend decreasing the height of the positive perforation to match that of the negative? The standard adopted by the Society is that *both* the negative and the positive perforations be the same as the present positive perforation. So far as formal action goes, we have done all that we can do. The rest is a question of propaganda. It is very difficult for us to know just how to induce every one to change. The film is available, according to the standard; all that has to be done is to order it; but we can not make people order the standard film if they choose to order the other.

MR. MITCHELL: That is exactly the point I make: a standard has been recommended that does not seem to be acceptable—they have so much old negative that they can not treat it; the positive film is more transitory. It might be worth going into the matter further to see whether the recommendation should not be changed to suit the existing conditions rather than the ideal.

MR. CARVER: That point has been studied carefully, and we have found no instances of apparatus in which negative film that already exists will not work satisfactorily in conjunction with the positive film. As a matter of fact, positive film will work all right in the camera without change, at least, in so far as we have been able to find out. Most cameramen would probably like to have the positioning pins changed were they to use the film with the larger perforations. One difficulty (I am sure it is not the only one) with the old type of negative perforation is the tolerance in the present sound equipment. The sound recorders will not work properly with the narrow perforation if shrinkage is greater than, I believe, 0.36 per cent. With the positive perforation, however, the tolerance is considerably greater, and that alone seems to be sufficient justification for insisting upon the positive type of perforation, as we have done.

REPORT OF THE SOUND COMMITTEE*

As noted in the Spring report,[1] the Sound Committee has addressed itself to four main projects. Upon the first of these, namely, that of establishing Primary and Secondary Frequency Reference Standards, considerable work has been done, principally because the Committee regards this project the most important, and for that reason concentrated its attention upon it. This report, therefore, will be restricted to that phase of the Committee's work.

As will be recalled, the first step in the project was to establish and calibrate prints that would serve as Primary and Secondary Frequency Reference Standards. That has been done, and the following instructions concerning their use have been prepared. The data indicate that an accuracy of ±0.5 db. may be achieved in direct comparisons between two films, and that results are reproducible at intervals to an even higher degree of accuracy.

FREQUENCY REFERENCE STANDARD OF THE SOUND COMMITTEE

Because of the inability of various organizations to make absolute measurements of the output from a given sample of sound record that would check, the Sound Committee decided to follow the precedent set by the Bureau of Standards in standardizing units of distance, weight, resistance, *etc.*, and has adopted a Reference Standard as a datum plane or bench-mark, to which all other frequency-film measurements can be referred. To this end, a certain film now in the hands of the Chairman of the Committee was selected as a Reference Standard, and has been marked *Primary Frequency Reference Standard VW, Print No. 1, Property of the SMPE Sound Committee.*

Although an effort was made to make the Primary Standard as nearly as possible a constant-output film, the various organizations that have measured the film do not agree as to its characteristic; nor is it important for our purposes that we know what it is. The measurements that have been made are merely for the purpose of deter-

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

TABLE I

Deviations (in Db.) of Secondary Reference Standards from the Primary Reference Standard (or Print No. 1)

Frequency (Cps.)	Number of Print											
	2	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
30	−0.5	−0.5	−0.2	0.0	−1.0	−0.5	−0.5	−0.1	−0.1	−0.3	−0.3	−0.2
50	−0.5	−0.2	+0.1	+0.2	−0.5	0.0	−0.1	+0.1	0.0	0.0	+0.1	+0.1
100	−0.5	−0.5	−0.2	0.0	−0.5	−0.5	+0.1	0.0	0.0	−0.2	0.0	0.0
250	−0.5	−0.5	−0.2	0.0	−0.5	−0.5	0.0	+0.2	+0.2	0.0	+0.2	+0.2
500	−0.2	−0.2	−0.2	−0.2	−0.5	−0.2	−0.2	−0.2	−0.3	−0.4	−0.2	−0.2
1,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2,000	+0.6	+0.3	+0.4	+0.5	+0.3	+0.3	+0.5	+0.7	+0.5	+0.5	+0.5	+0.5
3,000	+1.5	+1.5	+1.3	+1.2	+1.0	+1.5	+1.5	+1.6	+1.2	+1.2	+1.5	+1.5
4,000	+4.1	+4.1	+4.1	+3.3	+3.8	+3.8	+3.5	+3.7	+3.7	+3.5	+3.8	+3.7
5,000	+3.0	+3.0	+2.8	+2.5	+2.5	+2.5	+2.2	+2.4	+2.4	+2.4	+2.7	+2.2
6,000	+3.0	+2.5	+2.8	+2.2	+2.5	+2.5	+1.3	+1.3	+1.4	+1.2	+1.2	+1.0
7,000	+2.0	+2.0	+2.0	+1.0	+1.5	+1.5	+0.0	+0.4	+0.5	+0.2	+0.5	+0.2
8,000	+1.7	+2.5	+2.8	+1.0	+1.5	+2.0	+0.5	+0.9	+0.9	+0.7	+0.7	+0.5
9,000	+1.0	+2.0	+2.3	+1.0	+1.5	+1.5	0.0	+0.2	+0.7	0.0	+0.5	+0.2
10,000	+1.5	+2.0	+2.3	+1.0	+1.0	+1.0	0.0	+0.2	+0.7	+0.5	+0.3	0.0

mining the variations with age and hence the stability of the film as a Reference Standard. Information as to these variations will be made available from time to time, but not as to the characteristic.

As in the case of Reference Standards of weights and measures, it is neither desirable nor physically possible for every one to have direct access to the Primary Standard. The Sound Committee has, therefore, followed the procedure established in the case of many other Reference Standards, of employing *Secondary* Reference Standards. Consequently, additional prints were made of the same frequency negative and were marked *Secondary Frequency Reference Standard VW, Print No.___, Property of the SMPE Sound Committee.* Each of

TABLE II

Data Showing Reliability of SMPE Secondary Frequency Reference Standard as a True Standard of Reference

Frequency	*A*	*B*	*C*	*D*
30	−0.5	−0.3	0.0	. . .
50	0.0	+0.4	−0.2	0.0
100	−0.5	−0.3	+0.2	−0.2
250	−0.5	−0.3	0.0	. . .
500	−0.2	−0.1	−0.4	. . .
1,000	0.0	0.0	0.0	0.0
2,000	+0.3	+0.9	+0.5	+0.3
3,000	+1.5	+1.7	+1.5	+1.5
4,000	+3.8	+4.0	+3.8	+3.6
5,000	+2.5	+2.7	+2.7	+2.7
6,000	+2.5	+2.5	+1.7	+2.0
7,000	+1.5	+1.5	+0.5	+0.7
8,000	+2.0	+2.2	+1.3	+0.3
9,000	+1.5	+2.2	+1.0	+1.0
10,000	+1.0	+1.7	+1.0	. . .

Direct comparison with Primary Standard:

(*A*) On System No. 1, July 12th.
(*B*) On System No. 1, July 15th.
(*C*) On System No. 2, Aug. 8th.

Comparison with Primary Standard through intermediary test-film:

(*D*) Secondary Standard on System No. 2, Aug. 8th;
Test-film on System No. 1, July 12th; direct comparison with Primary Standard;
Deviation computed from these two runs. Frequencies omitted from column *D* were not included in the test-film.

All readings are in db., as read on a General Radio general-purpose level indicator and are deviations from the Primary Reference Standard (or No. 1 Print).

the Secondary Standards has been calibrated in terms of the Primary Standard, and the deviations noted upon a label pasted inside the cover of the film can. These prints are the property of the Sound Committee, and may be borrowed by any interested organization for the purpose of calibrating *privately owned* Reference Standards or test-films. In order to minimize the changes with use in these Secondary Reference Standards, it is of great importance that they be used as infrequently as possible. The Sound Committee will check the calibration of the Secondary Standards from time to time, as experience indicates the necessity of so doing.

The motive in establishing this Reference Standard has been to provide for the industry a tool that could be used for the study of specific problems. Detailed instructions will be prepared and issued by the Sound Committee from time to time on the exact procedure to be followed in compiling the data for such studies.

In order to furnish an idea of the relative uniformity of the Secondary Standards, Table I shows the calibration of each Secondary print in terms of the No. 1 Print, or Primary Reference Standard. Table II shows the consistency of measurements made at various times and with various machines, both by direct comparison and through an intermediate film or test-film. These data indicate that in direct comparisons an accuracy of ±0.5 db. may be expected; and that when an intermediate film is used, this accuracy will not be less except at the higher frequencies.

CALIBRATION OF PRIVATELY OWNED TEST-FILM

Probably the first step for each interested organization of the industry is to provide itself with a reliable test-film. For accuracy of results and ease of manipulation it is desirable that the film have an approximately constant output for all frequencies, although that is not absolutely necessary if the film is calibrated in terms of the Sound Committee's Primary Standard by means of a Secondary Reference Standard. When recording or obtaining a frequency test-film, care should be taken to include the frequencies that have been adopted by the Committee as being representative of the voice-frequency range, namely, 30, 50, 100, 250, 500, 1000, and every thousand up to and including 10,000 cps. This will permit the Sound Committee to correlate the data of the various organizations in the problems it has set out to solve.

When a frequency film has been obtained that appears to be satisfactory, it should be run upon a convenient reproducing machine and system (the better the machine and system the more reliable the results: preferably a machine without sprocket teeth), and the output at the various frequencies measured by a volume indicator or other suitable means. Repeat the run four or five times; then if the results check within a few tenths of a decibel, immediately run the Secondary Reference Standard once, without making any alterations in the system, and note the output at the various frequencies.

Next, to determine the deviation of the test-film at any frequency, take the average of the output readings of the film at that frequency and note the deviation between this average reading and the output reading of the Secondary Frequency Reference Standard. If the output of the film at that frequency is greater than that of the Secondary Standard, the deviation is plus; if less, the deviation is minus.

Pasted inside the can in which the Secondary Frequency Reference Standard is received will be found a table showing the deviation of the Secondary Standard from the Primary Standard at each frequency. Adding this value algebraically to the deviation between the test-film and the Secondary Reference Standard will then furnish the deviation of the test-film from the Primary Reference Standard. As an example:

If the test-film at 250 cps. gives an output of	+2.0 db.
And the Secondary Reference Standard under the same conditions and at the same frequency gives an output of	+1.0 db.
Then the deviation of the test-film from the Secondary Reference Standard would be	+1.0 db.
If the deviation for the Secondary Reference Standard as given in the table should be	−2.0 db.
Then the deviation of the test-film from the Primary Reference Standard would be	−1.0 db.
or, in other words, the output of the privately owned test-film would be 1.0 db. less than that of the Primary Reference Standard at 250 cps. if both were played under identical conditions.	

MEASUREMENT OF RECORDING FREQUENCY CHARACTERISTIC

One of the most important projects before the Sound Committee is that of achieving a greater uniformity in the frequency characteristic of sound records made in the various studios,[1] and as a first step in this project, the Committee desires to obtain information concerning the recording frequency characteristic now in use at those studios up to and including the release print. In order that these data may be directly comparable, the Committee wishes to have the results expressed in terms of the Primary Frequency Reference Standard; and in order to increase the accuracy of the results, it is desirable that the same method be used by every one in obtaining the data.

The Sound Committee recommends that the regular recording circuit as used at the present time, complete in every detail (including equalizer, *etc.*) from the microphone to the recording machine, be set up as for a regular "take." Replace the microphone unit by a resistor of the same value, and in series with it apply the standard frequencies (30, 50, 100, 250, 500, 1000, and every thousand up to and including 10,000 cps.) at a constant level, as read on a General Radio level indicator or any other level indicating device that shows no frequency discrimination. The input level should be so adjusted that all potentiometers and gain-controlling devices in the circuit shall be at normal setting and give a normal recording level on the film. Record about fifteen feet of film at each frequency, making certain that the film is up to speed when doing so.

The film should be processed in accordance with usual production practice (preferably attached in the developing machine to production negative) and a print made in accordance with the regular production procedure. If it is the normal practice of the studio to use the original negative in making release prints *this* test print should be measured as indicated below. If, on the other hand, it is the normal practice of the studio to re-record all sound upon a new release negative, the test print should be re-recorded, using the same machines, circuits, and equalizers as are used for regular production. The re-recorded negative should be given production development and printing, and the print made from this re-recorded negative should be used in making the measurements requested. In view of the fact that, in general, both original and re-recorded negatives are cut into the release negative, it is requested that data on both processes be submitted. Furthermore, in view of the fact that most studios use different equalization for dialog and music, it is requested that separate data on these two characteristics be submitted.

The print should be run four or five times upon the best recording equipment available, and the output measured at each frequency. Then, without making any changes in the reproducing equipment, run the privately owned test-film (or borrow a Secondary Standard from the Sound Committee), which has already been calibrated in terms of the SMPE Primary Standard, and note again the readings at the various frequencies.

To determine the deviation of the recording characteristic from that of the privately owned test-film at any frequency, subtract the output read on the test-film from the average of the output readings on the specially recorded film, taking particular notice of the algebraic sign. That is, if the newly recorded film gives an output at any frequency greater than that of the test-film, the deviation is plus; if the output is less, the deviation is minus.

Next, refer to the calibration of the test-film (or Secondary Standard) in terms of the SMPE Primary Standard; and for every frequency add the deviation of the test-film from the SMPE Primary Standard to the deviation of the newly recorded film from the test-film. These are the data desired by the Sound Committee. As an example:

At 500 cycles, the newly recorded film gives an average output reading of +2 db.
The test-film gives an output reading under similar conditions of....... +1 db.
Therefore, the deviation of the newly recorded film from the test-film is +1 db.
If the previous calibration of the test-film showed, at this frequency, a deviation from the SMPE Primary Standard of.................... −3 db.
Then the recording characteristic of the system deviates from the SMPE Primary Standard by.. −2 db.

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REFERENCE

[1] Report of the Sound Committee. *J. Soc. Mot. Pict. Eng.*, **XXV** (Oct., 1935), No. 4, p. 353.

PRESIDENTIAL ADDRESS*

H. G. TASKER

In the motion pictures which you have just witnessed is exemplified the keynote of the Society of Motion Picture Engineers from the day of its inception, nearly twenty years ago, until today as we open this Thirty-Eighth Convention of the Society. Nor will the keynote change as the Society continues down the years in service to the industry and to its membership, for that keynote is "Progress." Likewise it is the theme of my message to the Society this morning.

Although it is the common practice to trace the course of progress from some small and nearly forgotten beginning through periods of struggle to present accomplishment, and then to peer eagerly into the misty future to discern the progress yet to come, I should like to reverse the order and dip first into the future, after which we may, with some amusement, look to the present and the past to discover the heredity of this yet unborn future. So, ignoring the fast closing record of 1935, let us turn the pages of the book of time to the year 1940 and, carefully adjusting our spectacles, try to read the half-formed characters that are written there.

Without much difficulty I discern that the lusty youngster, "Sound," whose timely, or untimely, arrival in 1926 so thoroughly upset the motion picture family and whose cries of babyhood and shouts of youth both attracted and distracted theater patrons, has at last come of age and now exhibits the grace and ease of early manhood, seemingly a gentleman to the manner born. Not only has the frequency characteristic broadened, until it now, with smoothness and reality, embraces a range of thirty to ten thousand cycles, but also the disquieting and disillusioning background noises have been materially suppressed or controlled until the volume range of expression is comparable with that of the orginal sources. Moreover, a remarkable degree of uniformity has been achieved from theater to theater and from studio to studio, so that no longer is the attainable range of variation in frequency characteristics and in volume con-

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*Presented at the Fall, 1935, Meeting at Washington, D. C.

sumed in the inaccuracies of the art but is now available for the true rendition of the art of director and actor. I learn also that the sound now emanates from whatever portion of the motion picture screen is most appropriate to the scene, through the full development of audio perspective.

In the realm of photography even more startling changes have taken place. Not only has the fine artistry of 1935 been further advanced by the aid of better lenses and much finer-grained film emulsion, but those very elements have made possible a startling new effect, for the picture now stands out in full stereoscopic relief, yet sharp in all details. I see, too, that the art of process photography, which as early as 1935 had almost completely released the cinema from the fetters of time and space, has kept pace with the development of stereoscopic photography and has begun to overcome the seemingly insurmountable obstacles presented by process photography in three dimensions. I find that color, also, has at last attained its majority, and now clothes the picture like the raiment of a gentleman, neither shabbily nor blatantly but in such excellent taste and perfection of detail as to be almost inconspicuous.

These developments in sound and picture, it seems, have been accompanied and accelerated by technical advances in every branch of the science of motion picture making, but I am glad to say that progress is not confined to technical matters. With a great deal of pleasure I learn that the technical advances have been accompanied by substantial improvements in the human relations of the motion picture industry, especially as they affect the engineer. Through the aid of the Society of Motion Picture Engineers and other constructive agencies there has come about a much more sympathetic understanding, upon the part of the engineer, of the problems that beset the management and the artistic side of the industry, and because of this better understanding the engineer has bent his efforts still more effectively to the solution of the industry's problems. On the other hand, and in large measure through the same agencies, there has come about, upon the part of the managements, a better realization of the importance of engineering in this most scientific and yet most artistic of all industries. The year 1940 finds the very best of engineering brains no longer hectically, but now happily, engaged in the solution of motion picture problems.

Yet, perhaps, I may have misread in part this record of the year 1940. Certainly no millennium has as yet arrived, and I find recorded that the progress in human relations within the industry, though great, still leaves much to be done; that auditory perspective is too new a tool to have realized its full possibilities in the hands of the director and the artist; and that stereoscopic cinematography is likewise in its infancy, and though technically sound, is none the less the cause of much embarrassment to those who are trying to realize its possibilities as screen entertainment. At the bottom of the page I find this footnote: "The motion picture industry, despite having made tremendous technical advances within the last half decade, finds itself facing a still larger number of even more difficult technical problems than those that it faced in 1935."

Returning now to this 21st day of October, 1935, I need scarcely discuss the status of the motion picture science of today, for you are all quite familiar with it, or will be, when the technical sessions of this Convention draw to a close. You are aware, also, of the fact that the predictions that I have just made are no idle dreams; in every case, whether to result in success or in failure, the fundamental researches required are already in progress.

I am anxious, however, that you should realize that your Society, organized in 1916 "for the advancement in the theory and practice of motion picture engineering and the allied arts and sciences," has been, is today, and will still be in 1940, one of the great stimulating factors in the progress of the motion picture. It is most fitting, therefore, that this Society should now inaugurate an additional measure for stimulating the development of the art, comprising a Progress Medal which is to be awarded annually to some individual in recognition of an invention, research, or development which shall have resulted in a significant advance in the development of motion picture technology.

A most unusual design for the proposed Progress Medal was executed by Mr. Alexander Murray of the Eastman Kodak Company, approved by the Board of Governors, and generously donated by Mr. Murray to the Society. Dies were made, and the medal struck; a Progress Award Committee was appointed, which, after months of careful study, selected the first recipient of the medal; and on the occasion of the Semi-Annual Banquet next Wednesday evening the first award of the Progress Medal will be made.*

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*The award was made to Dr. E. C. Wente: See "Proceedings of the Semi-Annual Banquet at Washington, D. C.," in the December, 1935, issue, p.467.

Now the design of this medal (Fig. 1) is to my mind most uniquely symbolic of progress in the cinema. Referring to the right-hand side, the central series of horizontal panels afford opportunity to designate the name of the medalist and the purpose of the Award. They also carry a number of little triangular elevations, which many of you will recognize at once as representing bromide crystals. Above the inscription appears an H&D curve, symbolic of the classical researches of Hurter and Driffield, to whom the industry is indebted for clarifying the photographic basis of successful motion picture photography, both of sound and of scene. In curved panels to the left and the right appear sine waves, symbolic both of sound and light, which it is our modern purpose to imprison and later release for the enjoyment of the world-wide audience. An outermost circular panel bears the name of the Society.

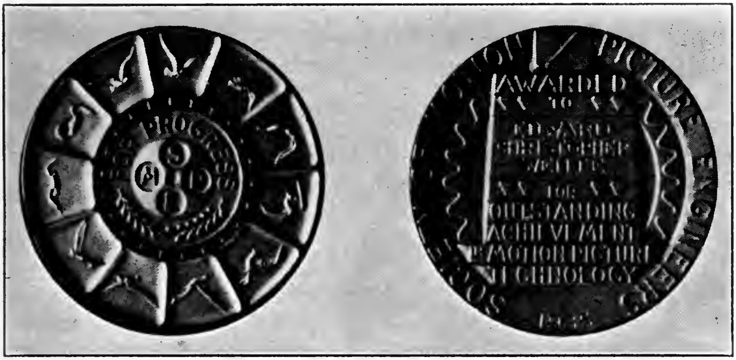

FIG. 1. The Progress Medal, showing on its obverse Marey's photographic images of a bird in successive phases of flight.

Turning to the left-hand view, we find that the central design is a replica of the official emblem of the Society, which, as you know, has its own origin in the motion picture reel. Above and around this emblem are embossed the words "For Progress," and below are laurel branches, symbolic of achievement.

Surrounding the central portion, a circle of film perforations forms a decorative motif which coöperates symbolically with what, to my mind, is the most outstanding feature of the entire design. Mr. Murray drew his inspiration for this portion of the design from the earliest known bit of cinematography, the work of the early French scientist, Eugene Marey, and while many of you may be familiar with Marey's work, there are doubtless many others who, like myself, would find it very interesting to delve into this nearly forgotten origin of the motion picture.

In his own day (1886), even as now, Marey was credited with being one of the originators of cinematography. In the translator's note introducing an English version of Marey's work on *Movement*, we find these remarks:

> "Instantaneous photography, especially that branch of it known as 'chronophotography' has already won for itself a recognized position among the methods of scientific research, and in the near future it is probable that it will be even more generally appreciated. Marey and Muybridge must undoubtedly be regarded as two pioneers of the method. . . ."

Marey himself was no seeker of laurels, and credits the actual conception of chronophotography to another. As an introduction to his chronophotographic method, Marey says:

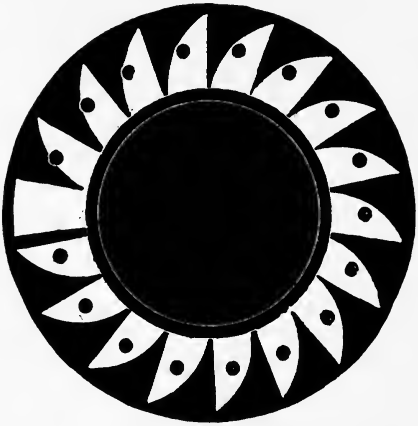

FIG. 2. Photographs of the planet Venus crossing the sun's disk, taken by Janssen with his "astronomical revolver."

> "A Mr. Janssen was the first who . . .thought of taking by automatic means a series of photographic images to represent the successive phases of a phenomenon. The honor is due to him of having inaugurated what is nowadays called chronophotography upon a moving plate. It was proposed to take a series of photographs of the planet Venus as it passed across the sun's disk, and for this purpose our learned colleague constructed his astronomical revolver. This instrument contained a circular sensitized plate, which at stated intervals rotated through a small angle, and at each turn received a new impression upon a fresh portion of the plate.
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> "The photograph (Fig. 2) which was obtained by this means consisted of a series of images arranged in a circular fashion. Each image represented a new position of the planet during the period of transit, and each was separated from its neighbor by an interval of *seventy seconds.*"

Although this interval between exposures was by no means comparable to the rapidity required for a photographic representation of the motions of every-day life, it appears that Mr. Janssen at least made the suggestion of applying a photographic series to the study of animal locomotion. He states:

> "A series of photographs of any particular movement, comprising the entire cycle of events, would be a most valuable means of elucidating the mechanism involved. In view of our present ignorance on the subject, one could imagine the interest of possessing a series of photographs representing the successive positions of a bird's wing during the act of flight. The principal difficulty would arise from the sluggishness of our photographic plates, for images of this kind require the very shortest exposure. But, doubtless, science will overcome difficulties of this kind."

It should be remembered, of course, that the representation of motion through animation, similar to that still employed by Walt Disney in the exceedingly popular *Mickey Mouse* and *Silly Symphony* cartoons, had preceded by some years the work of Janssen and of Marey. Janssen undertook to point out that his proposal, in contrast to the synthetic representation of motion, would provide an *analytical* study of movement.

Nevertheless, the photographic revolver by Janssen was not to be the first device applied to chronophotographic studies of motion. It remained for Mr. Muybridge, of San Francisco, to discover, by means of a method rather different from that of Janssen's, the analysis of equine locomotion, as well as that of man and various other animals. In Muybridge's method a number of cameras were drawn up alongside a race-track. Electric wires, stretched across the track at intervals, communicated with electromagnets, each of which held the shutter of one of the cameras tightly closed. The horse, in following the track, broke the wires one after the other, and brought about the instantaneous opening of each corresponding shutter. Each exposure allowed a photograph of the animal, in one or the other of its positions, to appear upon the plate. The resulting series of stills showing the successive phases of motion was admirably suited to this scientist's purpose, but the apparatus, as was soon discovered, was of little use for studying movements of birds.

Now birds, as it happened, were a subject that greatly interested Mr. Marey, and after studying, with meager results, some random photographs of birds in flight made for him by Mr. Muybridge, Marey determined to invent an apparatus,

> "based upon the same principles as that of Mr. Janssen's, but capable of giving a series of photographs at very short intervals of time ($^1/_{12}$ of a second instead of the 70 seconds which separated the photographs of Janssen's astronomical revolver) so as to procure the successive phases of movements of the wings."

This instrument, gun-like in form, made it possible to follow the flight of a bird by aiming at the object in the manner of Fig. 3(*a*). Ignoring for the moment the mental reactions of the artist as revealed by the fantastic appearance of the gun-strap, the general arrangement of the "gun" may be observed in Fig. 3(*b*). The extensible "barrel" contains the photographic lens, and is graduated for ease in focusing. The circular breech contains the photographic plate, the rotating shutter, and the clockwork mechanism. In the interior view, Fig. 3(*c*), is shown the twelve-windowed aperture plate against which the photographic plate is pressed and some of the mechanism by which the plate is rotated in true intermittent fashion. In the words of the author:

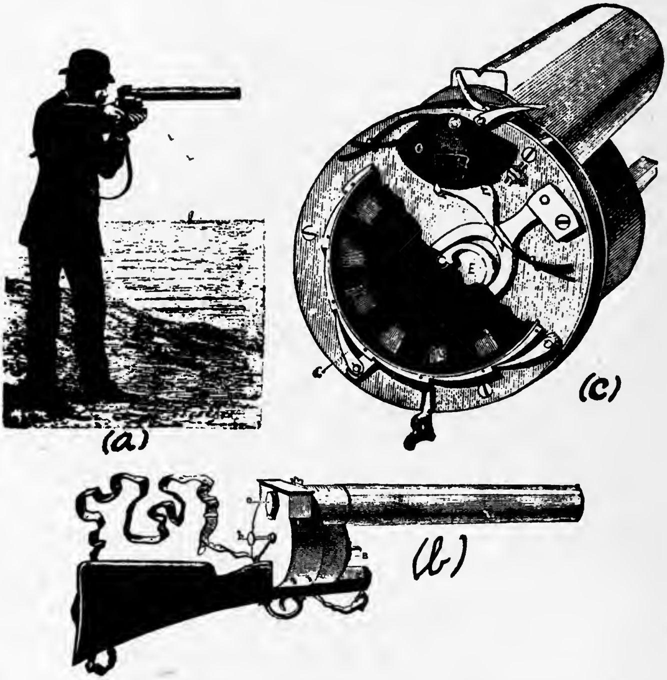

FIG. 3. (*a*) Marey's design of the "photographic gun"; (*b*) general arrangement of the "gun," showing the extensible "barrel" containing the lens; (*c*) the 12-windowed aperture plate against which the photographic plate was pressed, and some of the mechanism for rotating the plate intermittently.

> "The moment the trigger was pulled, the sensitized plate received an impression, then moved on to receive another, and so on, but *always stopping* each time that the opening of the shutter allowed the light to fall upon the plate."

In Fig. 4 we see the result, and in it the inspiration for Mr. Alexander Murray's design of the Progress Medal. Made upon a gelatin plate sensitized with bromide of silver, the successive photographs of a flying gull are shown at intervals of $^1/_{12}$ second. Says Marey:

> "These little images, when enlarged by projection, furnish curious details with respect to the position of the wings and the torsion of the remiges by the resistance of the air, but in the majority of cases the images are too small to stand enlargement."

This most fascinating piece of research and invention was accomplished with but one end in view, the scientific study of animate movement, and the inventor had no dream of the vast amusement industry that would some day grow out of his simple invention. It seems always thus. Scientists devise and discover for purely scientific ends, while others adapt to commerce or amusement the principles and devices that they have brought forth.

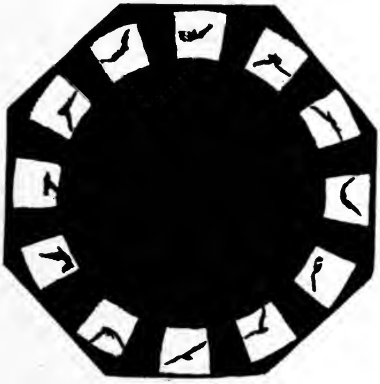

FIG. 4. Marey's bird in motion, the inspiration for the design of the SMPE Progress Medal.

In order to appreciate Marey's contributions fully, we must add one further word regarding his subsequent work. He soon realized the limitations of his ingenious apparatus and, as he stated:

> "The weak point of the photographic gun was principally that the images were taken upon a glass plate, the weight of which was exceedingly great. The inertia of such a mass, which *continually* had to be *set in motion and brought to rest*, necessarily limited the number of images. The maximum was 12 in the second, and these had to be very small, or else they would have required a disk of larger surface, and consequently of too large a mass.
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> "These difficulties may be overcome by substituting for the glass disk *a continuous film* very slightly coated with gelatin and bromide of silver. This film can be made to pass automatically, with a rectilinear movement, across the focus of the lens, come to rest at each period of exposure, and again advance with a jerk. A series of photographs of fair size can be taken in this way. The size we chose was 9 centimeters square, exactly the right size to fit the enlarging camera by which they could be magnified to convenient proportions. As the continuous film might be several meters in length, the number of photographs that could be taken was practically unlimited."

"The necessary elements for taking successive images upon a continuous film are united in the apparatus shown in Fig. 5. The apparatus has a special compartment, the photographic chamber, in which the sensitized film is carried. To admit light there is provided an apertured admission shutter. At each illumination the light passes through the aperture, and forms an image upon the moving film, which has previously been brought into focus. The film unrolls itself by a series of intermittent movements, by means of a special mechanical arrangement which enables it to pass from one bobbin to another."

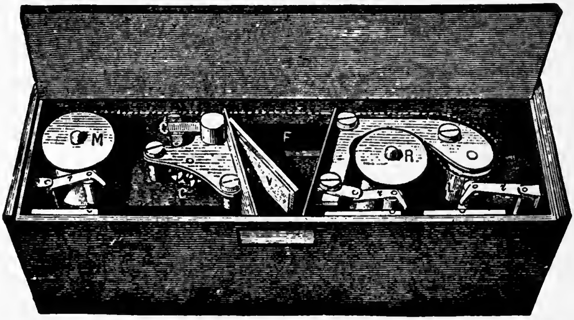

FIG. 5. Marey's apparatus for taking successive images upon a continuous film.

FIG. 6. Photographs taken by Marey to show that it was necessary to arrest the motion of the image during exposure: (*left*) film in motion during exposure; (*right*) film at rest during exposure.

Not only did Marey clearly understand the necessity for arresting the motion of the photographic surface during an exposure, but he even engaged successfully in arguments with other scientists who felt this complication to be unnecessary. Said Marey:

"Some people have thought that by using such a complicated apparatus as that which we have employed for arresting the movement of the film we have given ourselves unnecessary trouble, and it has been said that for very short exposures the movement of the film might be neglected. It would be easy to prove by calculation that during the period of the exposure, say, 1/1000 part of a second, the film would move enough to deprive the photographs of that clearness upon which their value depends. But it is simpler and perhaps more convincing to show by an experiment that without these periods of arrest good images are not to be obtained. By alternately suppressing and inducing an arrest of the film at the moment of exposure, we obtained a series of images which were alternately blurred and distinct.

"Two such consecutive images are shown (Fig. 6). The different degree of definition is so obvious that it is useless to insist further upon the necessity of arresting the film during the period of exposure."

After this brief review of his remarkable work I am prompted to propose that we bestow upon Eugene Marey, long deceased, the well earned title of "Father of the Motion Picture." I, for one, am doubly grateful to Mr. Alexander Murray, first, for giving to the Society a most beautiful and symbolic design for the Progress Medal, and, second, for affording us frequent occasion to remember the outstanding work of a pioneer upon whose accomplishments our very presence here depends.

CONTINUOUS PHOTOGRAPHIC PROCESSING*

H. D. HINELINE**

Summary.—*The trend of development of continuous photographic processing, from the beginning of the art to the more recent elaborations of equipment, is discussed from the point of view of the patents issued from 1886 on. An appendix contains a list of patents describing minor improvements and refinements in processing equipment.*

When an industry completes the stage of preliminary experiment and development, it is confronted with the problems that are inherent in quantity production. The photographic industry is no exception in this respect, and very early in photographic history the requirement for quantity methods of production appeared. But, as is usually the case in the photographic field, relatively little information has been published in regard to commercial methods of handling and finishing sensitive materials in large quantities and by continuous processing methods, and what little published information there is is largely to be found in patents. The most important field of continuous photographic processing is, of course, that of the motion picture industry, and it is the motion picture laboratories that have developed apparatus and methods for the continuous processing of photographic materials to the highest stage.

But continuous photographic processing antedates the motion picture by many years. The first patent dealing with continuous photographic processing is that of John Urie, British Patent No. 16,237, of 1886. The patent is very interesting, indeed, for it contains the germ from which grew practically all the subsequent systems of continuous photographic processing. Urie dealt with bromide paper only, particularly picture postcards printed automatically upon a roll of paper. He fed the exposed strip of bromide paper from a reel into a tall narrow tank of developer, and under rolls carried upon movable frames. The frames each carried three rollers, so that

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** New York, N. Y.

the film made four passes through the height of the tank; and the frames could be raised and lowered to control the depth of immersion and thereby control the length of time of development. Two tanks of developer are shown, each equipped with a drain valve, and a supply storage tank. From the developer tanks the paper was drawn over a constant-speed traversing roll by friction and dropped into a tank of rinse water, fresh rinse water being continuously supplied and allowed to overflow. From the rinse water tank the strip of prints was carried to two tanks of fixing bath, similar in form to the developer tank and similarly equipped with rolls, racks, and drain and supply storage tanks. From the fixing bath, the strip was drawn over another feeding roll and dropped into a tank of wash water from which it was later withdrawn and rolled up wet upon a reel. Urie does not show a drier. He does show and describe his entire system as being mounted in a large tray to prevent undue spillage of solution. He shows and stresses constant speed of travel of the material, and shows and stresses variation of immersion time in the solution. He speaks of return of the solution from a drip tank to the storage tank for re-use. The only important point Urie missed was that of temperature control, but he did not need to control his temperature accurately, because he was able to follow the development by inspection and regulate the development time accordingly.

Urie's patent was followed eight years later by U. S. Patent No. 525,849, issued September 11, 1894, to E. F. Macusick, who also was dealing with photographic paper rather than with ciné film. But the side view of his machine, as shown in his patent, is hardly distinguishable from a diagrammatic side view of some of the more successful modern ciné developing outfits. He drew his printed paper from a reel and passed it in succession through a series of tanks of solution, feeding and conveying rolls being provided over the partitions between successive tanks. He also provided carrier cords on the edges of the paper, as has since been suggested and patented for ciné film.

Not alone was the need felt for quantity production in the finishing end of the photographic field, but also in the plants for the manufacture of sensitive material. This is shown by Patent No. 358,848, issued to George Eastman (and another) for a machine for coating wide strips of nitrocellulose film, the patent showing the coating trough with means for producing the vertical upward movement of the film to drain off excess emulsion and smooth the coating, and the horizontal chilling section as well as the drier with a chain conveyor and looper bars to carry the coated film in festoons through the drier room.

Another Patent, No. 588,790, issued to Blair (and another), is decidedly interesting because of the showing of the large coating roll upon which the dissolved celluloid or "dope" is spread, dried, and stripped off to make the film support, and then coated with silver emulsion and passed to the drier.

Urie and Macusick both utilized a style of processing system that may be most conveniently described as the "tube" type.

Thus it will be observed that the first workers in the field of continuous photographic processing machinery utilized deep-tank systems, with several passes of the strip of material in the tanks. This was probably due to the fact that these early workers usually had their material in fairly wide strips, from several inches to a foot or two, as distinguished from the narrow ribbon of celluloid in which the motion picture worker is interested. After the broad idea of continuous processing through a series of containers for the several successive solutions had been worked out and exemplified in these constructions, the later types of construction diverged into several typical forms, which included, besides the deep-tank system of the early workers, the shallow-tank system in which one tank of considerable length was provided for each solution; the so-called tube system in which a series of relatively deep tubes were provided for each solution; and the pipe system in which one long tube containing a single bight or loop of film was utilized. Similarly, the method of conveying the film through the processing members took several divergent forms, the early workers using friction rollers above the tanks; which procedure has continued to find favor with some workers through the subsequent development. Other forms utilized gears, chains, or tapes of various kinds; and for motion picture film, various forms of sprocket gears. Thus we find at last the germ for substantially all the subsequently constructed forms of continuous processing machinery in the systems of the very first workers.

Next in order of production appears to have been what may be called the trough type of processing system, as exemplified by Patent No. 607,649, issued July 19, 1898, to Arthur Schwarz. This patent shows a series of long shallow troughs carried in a frame one above the other. The system dealt primarily with paper rather than with film, and fed the paper from a reel through a trough of developer, then through a trough of fixing solution, and then through two troughs of wash water to a steam-heated drier and rewind spool. It may be noted that this patent is the United States equivalent of a German patent, and that, as is usual under such circumstances, the showing is distinctly sketchy.

However, Schwarz seems to have had difficulty with his shallow-trough system, because soon after his first patent he secured Patent No. 623,837, issued April 25, 1899, in which he utilized a tube type of tank with a considerable number of successive tubes of solution and driven feed rolls over each tube, all the rolls being driven at the same speed from a common line shaft. It is to be presumed that he encountered difficulties with the swelling of the paper as it absorbed water, but his system offered no means for correcting this.

Schwarz, however, was not the only inventor working upon this type of system, as is shown by British Patent No. 19,726, of 1896, which shows a developing system for paper, utilizing a series of tanks, as distinguished from tubes or troughs, with several passes of the material in each tank. Along the same lines is the showing of British Patent No. 21,679, of 1897, issued to DeKato, who shows quite an extensive paper developing machine with speed control, immersible frames, solution storage tanks, *etc.*

An interesting angle of continuous processing is to be found in Patent No. 665,982, issued to Thornton, who built a coater for applying a considerable number of very thin layers of emulsion upon film or paper, with drying ovens between each coating stage to obtain rapid drying.

These patents show generally the stage of development early reached for the continuous processing of paper, but none of them dealt directly with motion picture film. This is not surprising in view of the fact that most of them antedated the invention of the motion picture. (Patent No. 493,426 to Edison is of interest as showing approximately the date of Edison's first motion picture invention.)

The first occurrence in this list of publications of a patent showing a system for developing ciné film is British Patent No. 13,315, of 1898, issued to Hepworth. Hepworth's apparatus consists of a plurality of long shallow troughs placed side by side, and having feed sprockets at each end and a large tank of rinse water underneath. The complete system is described as including a perforator for perforating the film, and an automatic printer from which the film was fed into the first or developer trough by a sprocket, drawn through the trough over a movable rod which controlled the length of time of immersion, and then dropped into the rinse tank. Thereafter, it was fed to other solution tanks in succession, such as the fixing and toning tanks, then through a final wash trough to a drier and rewind spool. Hepworth included even an alarm apparatus to indicate breakage of the film or low solution level. It does not appear that any particular means of temperature control was included, but he does expressly mention the advantages of sprockets for positive drive of the film through the several baths.

A patent that is of interest, although not directly in point, is British Patent No. 22,614, of 1899, issued to Pollak. This patent shows a photostat type of machine in which the successive prints are impaled upon tacks on an endless belt, and carried thereby through the several solutions to the discharge end. Workers in the motion picture field have attempted to utilize conveyor chains on sprockets as suggested by Pollak.

These patents dealt with the finishing of photo-material film, but Patent No. 676,314, issued June 11, 1901, to C. E. Hearson (and British Patent No. 995, of 1900) dealt with a machine for coating a strip of film of ciné width. This patent is particularly interesting because of the fact that it shows a drier having top and bottom rolls of considerable length over which the film is carried in a spiral path for drying, the film being led from the coating machine over the top roller at one end, down to the bottom roller, back to the first roller at a point a short distance sidewise, and so on, until the available space on the rollers was utilized; then on to the other side of similar rollers, sufficient to complete the drying, after which the coated film was reeled. It may be noted that this spiral travel path kept the wet, sticky emulsion away from contact with its carrying means at all times and prevented injury to the delicate film surface. This appears to be the first occurrence of a machine showing the spiral path for handling ciné film.

United States Patent No. 703,671, issued July 1, 1902, to Schwarz, is substantially identical to British Patent No. 21,679, of 1897, issued to DeKato.

Patent No. 720,708, issued February 17, 1903, to Latta, is of interest because, while it discloses a continuous developing machine for paper only, it shows elaborate mechanism for the recirculation of the solutions and very shallow troughs utilizing a minimum of solution.

Patent No. 721,839, issued March 3, 1903, to Schwarz, shows still another form of paper processing machine with variable-speed drive, solution storage tanks, and a clutch member between the tank sections to permit obtaining a large loop of paper in the rinse tank.

Patent No. 757,323, issued April 12, 1904, to Lienekampf and Nauck, shows a trough system for processing paper strip with an intake feed loop convenient for splicing a new reel of printed paper to an old one, as well as a variable-speed drive and a circulating pump for one of the solutions.

Patent No. 830,741, issued September 11, 1906, to Prentiss, shows a printer station and a plurality of solution troughs with conveyor bands, and a conveyor chain through a long wash trough.

It is of interest to note that up to the date of these patents none of them had discussed the question of temperature control. However, a good discussion of temperature effects is to be found in British Patent No. 22,456, of 1907, issued to Watkins.

Of course, blue-printing is simple photography, but even blue-printers found continuous processing desirable, as is shown in Patent No. 891,289, issued June 23, 1908, to C. F. Pease, whose machine consisted of successive water tanks, rolls for carrying the paper through the tanks, rollers in the loops of paper in the water, and a drier consisting of two large, heated rolls.

The spiral path idea reappears in Patent No. 939,350, issued to Thompson, who describes an elaborate multi-spiral drier for use with ciné film.

The coating of the original film base in the factory and the drying of it in large loops through a drying loft appears to have suggested to ciné workers the possibility of handling ciné film in the same manner, as is shown by Patent No. 948,731, issued to Ivatts for a conveyor belt with hooks and an automatic control for attaching loops of ciné film thereto for convenience in carrying them through a drying loft.

The first appearance of a suction means for removing excess moisture seems to be in Patent No. 953,663, issued to Hoglund, in whose machine the film was passed from a reel type of developing machine through a suction device and a single-pass drying oven to a take-up reel.

Patent No. 970,972, issued to Thompson, a prolific worker in the field, shows a multi-spiral conveyor in combination with means for dampening a film slightly and applying a nitrocellulose varnish to the emulsion face for lengthening the film life.

Patent No. 971,889, also issued to Hoglund, shows a vacuum-cleaner system for removing dust from a film, and with it a supply reel, means for printing marks upon the film edges, and a rewind.

A continuous drier that may be of some interest to workers in the field is shown in Patent No. 1,002,634, issued to Brandenberger for a machine for drying cellophane films.

Another patent of some interest is No. 1,109,208, issued to Davis and McGregor, which shows a series of shallow tanks with sprocket rollers, hooded to keep the film upon them, in a spiral path with a similar drier, the hooded sprockets being roughened to keep the film in place and insure its travel.

Patent No. 1,141,464, issued to Javault, shows a processing machine made up of several tanks, each with long top and bottom rollers to carry the film in a spiral path through the tanks of solution to a drier. The showing is not very detailed, but is of interest in connection with the later Gaumont patents.

An interesting type of developing machine which may be called the pipe type, as distinguished from the tube type, is shown in Patent No. 1,143,892, issued to Ybarrondo. This patent shows a developing system consisting of a long pipe with a center guide down which the film is conveyed. The pipe is indicated as being many feet long, probably hundreds of feet long, since it appears to have been adapted to take a full camera spool of film. A not unreasonable guess might be that Ybarrondo was working at the Fort Lee, N. J., studio, and planned to run his pipe containers down the side of the hill or down the Palisades. If so, one wonders how good his temperature control would have been, even though he appears to have provided for rapid solution circulation through pipe manifolds, and temperature control means for heating, which must have been quite vital.

Patent No. 1,150,609, issued to Marrette, shows a drier with an alarm signal to show film breakage, and counter-current air travel with two strips of film side by side.

The first suggestion of the continuous processing of color film is to be found in patent No. 1,169,096, issued to Thornton. His machine conveyed the film through a spiral path over the carrying rollers for imbibition of the dye into a prepared gelatin image.

Patent No. 1,172,074 is of interest because it shows a chain carrier for paper prints, with print grippers upon the chain. It shows temperature control means and all of the processing, including the drying, upon a single chain and clamp.

A very interesting patent is No. 1,177,697, issued to Gaumont on April 4, 1916. This is one of the few patents in the list upon which there has been litigation (Cinema Patents *vs.* Warner Bros.). It shows a plurality of tanks in which are provided upper and lower crowned spools upon shafts affording a spiral path of travel through the solution, one spiral in the first tank for developing, two spirals in the second tank for fixing, and four spirals in a third or washing tank.

The patent also shows toning or tinting tubes and a drier. This patent is of particular interest because of the showing of a large storage tank for solution with a circulating pump and a temperature control coil. However, in view of the large amount of prior art, as pointed out above, the patent was held to be of limited scope, and the claims, while valid, limited to the precise structure shown in the patent and, therefore, not infringed by the tube type of machine, against which suit was brought.

An accompanying patent to the preceding is No. 1,209,096, also issued to Gaumont on December 26, 1916. This patent covers a drier for use with the previously described solution system or wet end. It shows similar crowned rolls and means for spiral travel of the film through the drier, and also shows a safety loop between the tanks and the drier for protection of the film against breakage between sections in the event that minor differences in speed occurred between sections. It also shows an alarm system in the drier which will stop the motor if the film breaks in the drier. This patent also was held to be of limited scope, and valid only for the precise structure shown.

Patent No. 1,260,595, issued to Thompson, shows a processing system in which the spiral path is used with variously sized rollers to compensate for shrinkage of the film during drying. This patent also shows a suction device for removing excess moisture, and a weighted roller in a loop between the solution tank and the drier.

Patent No. 1,261,056 likewise is of some interest because of its disclosure of means for splicing the film between successive reels as they are fed to the processing machine, and is the first disclosure of means for maintaining the threading of the machine. Previous machines have made no suggestion of means for threading the system, nor of means for maintaining the threading between intervals of operation, obviously quite important matters.

Difficulties are, of course, encountered in the handling of film upon sprockets, and some workers believe that a full friction drive would be desirable. Such a system is shown in Patent No. 1,281,711, also issued to Thompson, in which the friction was maintained by weighted rollers. This machine likewise conveyed the film in a spiral path in each tank.

Another question untreated in the previously discussed patents is that of the removal of dirt. Patent No. 1,299,266, also issued to Thompson, shows a film cleaner between the solution tanks and the driers, consisting of four squares of fabric upon a drum, which wipe the film during its passage between the tanks and the drier.

Ybarrondo appears to have elaborated upon his pipe type of machine in Patent No. 1,319,026, in which he shows a number of pipes with rollers at the bottoms and means for feeding the film through them sequentially. He also shows a lamp system for viewing the films by transmitted light during the processing, this being the first detailed disclosure of a specialized examination device in a continuous processing system.

Patent No. 1,328,424, also issued to Thompson, shows a spiral type of processing machine with a gear-and-chain carrier system, the film being attached to the chain and carried thereon. The question might well be raised as to the means for accommodating the swelling and shrinkage of the film during processing.

Patent No. 1,348,029 is the first occurrence of the idea of a film floated upon a solution surface. This patent shows a very long trough containing dye solution upon which the film is floated for imbibition of the dye in making color prints.

Another color process is shown in Patent No. 1,351,834, issued to Capstaff. In this device a series of rollers dip the lower portions in the dye solution and convey them upward to the under surface of a film being carried along over the rollers. This was primarily an experimental laboratory development.

An interesting offshoot is to be found in Patent No. 1,364,321, issued to Rose, which shows a developing tank and a fixing tank adapted to be attached directly to the camera retort to permit the cameraman to develop a short length of film directly from the retort to verify his exposures.

An interesting device produced in the course of elaboration of the conveyor-chain type of machine is shown in Patent No. 1,367,435, issued to F. E. Smith; the machine being constructed with a double conveyor-chain carried in a spiral path, with the film held by its sprocket holes alone between the two chains while being carried through the successive solutions. This type of machine, in common with various others, may be questioned as to the means of providing for swelling and shrinkage of the film while impaled by its sprocket holes upon the chain, and the question may also be raised as to the mechanical efficiency of a pair of chains carried in a spiral path.

Another of the flat-tank type of machines is disclosed in Patent No. 1,377,887, issued to Hubbard. The construction shown is of shafts at the ends of the shallow tanks to carry the film in a spiral path, the tanks being positioned one above the other. This system did not utilize the sprocket holes in the film for carrying purposes, but depended upon a friction drive between the rollers and the film.

It is, of course, desirable that as little solution as possible shall be carried from tank to tank, and, accordingly, various means have been suggested for removing excess fluid, such as the form shown in Patent No. 1,380,279, issued to Wescott. This mechanism consists of two pairs of opposed air jets acting upon opposite sides of the film to remove the loose moisture by air-blast. Such a mechanism is much less dangerous to the film and occupies much less space than the vertical rise of film required to remove the moisture by gravitational drainage.

Still another of the tube type of processing machines is shown in Patent No. 1,385,403, issued to Sentou and Jacquet. This machine includes crowned rollers with guards, and the bottom roller is carried on cords running to the bottom of the tank.

Another form of moisture-removing jet device is shown in Patent No. 1,407,543, issued to Hubbard, disclosing an elaborate system of two opposed flat air jets co-acting on opposite sides of the film.

Patent No. 1,435,764 shows another form of shallow tank with the film floated upon the surface for imbibition of die solution in the manufacture of colored film.

A somewhat odd and unusual structure is to be found in Patent No. 1,444,818, also issued to Wescott. This patent discloses an elaborate system of skewed rollers mounted both over a narrow tank and at the bottom of the tanks in the loops between sections. The structure is peculiar, and the purpose not clearly brought out.

In any continuous processing system, there is more or less constant danger of injury to the film. This is particularly the case where the sprocket holes are utilized for carrying the film forward, and various workers have attempted to minimize this danger. Patent No. 1,461,794, issued to DeMoos, discloses a tube type of machine, utilizing sprockets for conveying the film through the solutions, the sprockets having only one set of teeth, the purpose presumably being to reduce the danger of injury to the film.

With a given developer formula the amount of development is a function of the speed of travel through the machine and also of the depth of submersion in the solution, the development time at a given speed in feet per second of film being determined by the length of the loops of film submerged in the solution. Patent No. 1,467,106, also issued to DeMoos, discloses an indicator to correlate the depth of submersion of the film and the speed of travel of the film, so that as the depth of submersion increases, the speed of travel may also be proportionately increased.

Not alone do the tanks, and the conveyors therein, of any kind of continuous processing system, take various forms, but the drier systems likewise assume varied shapes. The earlier drying reels for batch processings were quite satisfactory, and it is not surprising that a worker should attempt to adapt the reel to continuous processing. Such a system is shown in Patent No. 1,473,542, issued to Chanier (and another). The disclosure in this patent is distinctly sketchy, but it shows roughly a pair of reels, one above the other, for the film, which is conveyed thereover in a spiral path, the reels being set with the axes at a slight angle to insure travel of the film. Of course, during the processing of the film, a substantial amount of swelling of the film during immersion and processing occurs in the wet end, and this swelling largely disappears during the drying operation in the drier cabinet, making particularly necessary some means for compensating for the change in length of the film. Patent No. 1,479,453, issued to Carlton, shows a drier with swinging arms at the bottom to adjust the slack and to compensate for the drying shrinkage.

Some workers appear to have had difficulty in the way of losing rollers in the bottom of a processing tank when the film breaks, and have regarded it necessary to provide preventive means. Such a structure is shown in Patent No. 1,495,678, issued to Ybarrondo. This patent discloses chains for carrying the bottom rollers, but appears to be hardly a vital refinement.

When any material is processed from rolls, it is necessary to make flying splices, and this need occurs in the film processing industry as well as in the newspaper printing field (the printer can use paste, but the photographer can not). Patent No. 1,540,831 shows a running splicer for ciné film in which, as a prior reel empties, a bail falls and hits a stapling machine, driving a staple through the end of the leading film and the beginning of the following film to fasten them together in order to carry the second film through the processing. This procedure appears to be merely making automatic what was long prior manual practice with a wire stapling machine.

Another refinement in the processing is shown in Patent No. 1,542,530, issued to Salins for a system in which several spirals of film are carried through a single tank and means are provided for stopping the input of film and raising the bottom rolls to shorten the development time; an ingenious idea, but perhaps unnecessarily complicated in comparison to the simple procedure of changing the speed of film travel.

Another variant is shown in Patent No. 1,555,957, also issued to Ybarrondo, in which the inventor suggests the use of a wide belt carried through the processing tanks with films stapled to it, the idea apparently being to process several films simultaneously.

Still another form is shown in Patent No. 1,568,344, issued to Moody (and another), for a structure in which the film is carried by a chain with side clasp, gripping the edges of the film for conveyance through the processing steps.

Shrinkage difficulties in the driers appear to have inspired various other workers to the production of driers with shrinkage compensation. Still another form is shown in Patent No. 1,569,156, issued to Thompson, for a structure utilizing a spiral path in the drier, with successively smaller drive wheels toward the output end to traverse the film more slowly and thereby compensate for shrinkage during the drying operation. It may be remarked that such compensation is not necessary when the film is traversed over sprockets, since the number of sprocket holes traversed for a unit time is constant without regard to the shrinking or swelling of the film.

Any continuous processing system in constant operation will exhaust the strength of far more solution than can be maintained in conveniently sized tanks before the solution oxidizes seriously, and it appears that practically all the commercial processes utilize storage tanks for developing solution and fixing solution, from which the solutions are circulated by pumps. It is not obvious why a continuous processing system should be built to contain a minimum amount of solution unless it be for occasional brief usage, where it is desired to furnish the system with solutions at a minimal cost. This may be the case in the structure shown in Patent No. 1,570,809, issued to Wescott for a system utilizing flattened tubes, the film traversing a spiral path so as to utilize a relatively very small quantity of solution.

Some workers have elaborated extensively upon the mechanism by the provision of means for modifying the treatment of various parts of the same strip of film, as by variable submersion, stoppage of various portions of the film, *etc.*, as shown in Patent No. 1,579,399, issued to Salins.

Still another elaboration is shown in Patent No. 1,592,924, issued to Carbenay, the most interesting feature of which is the provision of a mechanical uncoupling mechanism to vary the length of the film loop in the tank, thereby varying the development time.

Still another elaboration is shown in Patent No. 1,595,294, issued to DeMoos, disclosing a drier system in which are incorporated a mechanism for indicating shrinkage of the film and a stop to prevent undue length of film loops in the drier.

A neat elaboration of the development time control is shown in Patent No. 1,603,512, issued to Carlton, disclosing a system of change-speed gears for the driving mechanism and minute adjustment of the depth of immersion of the film.

Air for removing excess moisture must be under substantial pressure and compressed air is not inexpensive; nor is it easily obtained free from oil and dust. These difficulties apparently have led to the proposal of other means for removing moisture from the film, such as that shown in Patent No. 1,607,417 issued to Wescott, which discloses a chamois skin belt running in contact with the film to remove moisture, with a wringer roll for keeping the chamois belt in absorbent condition.

The foregoing patents disclose practically all the requirements for a satisfactory form of continuous processing mechanism, and the patents listed in the appendix hereto cover only refinements, which, while convenient, are not essential for efficient film processing. This fact has been brought out by the Court holding in the case of Cinema Patents *vs.* Warner Bros. Pictures, in which suit was brought on the Gaumont Patents Nos. 1,177,697 and 1,209,696. These patents have expired since the bringing of the suit. The Court held, and was sustained upon appeal, that the patents contained claims valid for protecting the precise structure shown in the Gaumont patents—that is, tanks with crowned rollers therein for carrying the film in a spiral form in the tank, and driers with similar crowned rollers for carrying the film in a spiral path—but that the claims were not entitled to any substantial breadth of equivalency because of the large amount of prior art, as pointed out above. Accordingly, the Court found that the Warner simple type of tube machine with carrying sprockets did not infringe these patents.

It, therefore, appears that the motion picture industry has developed efficient and satisfactory continuous film processing machinery adapted to convenient operation, which is free of patent limitations and open to all who wish to utilize machinery for continuous processing.

The above abstract of patents discloses most of the features for convenient and efficient processing machinery, but there have been many minor improvements made and patented which would require undue space in this article if they were abstracted. However, for those who are directly interested in the matter, the following patent bibliography is offered. Any of these patents may be obtained from the United States Government, Commissioner of Patents, upon request, at a cost of ten cents per copy.

APPENDIX

Patents Disclosing Refinements in Continuous Processing Mechanisms

No.	*Inventor*	*Title*
358,848	G. EASTMAN, *et al.*	Apparatus for manufacturing sensitive photographic films
588,790	T. H. BLAIR, *et al.*	Method of and apparatus for making photographic films
607,648	A. SCHWARZ	Continuous photographic printing apparatus
630,500	J. K. GRAEME	Developing apparatus
664,982	J. E. THORNTON	Manufacture of photographic sensitized materials
717,021	A. POLLAK	Photographic developing apparatus
720,708	P. LATTA	Apparatus for developing, fixing, and toning kinematographic or other photographic films
721,839	A. SCHWARZ	Apparatus for developing, toning, and fixing photographs
757,323	O. LIENEKAMPF, *et al.*	Photographic developing apparatus
830,741	F. S. R. PRENTISS	Multiple printing, developing, fixing, washing, and drying apparatus
864,123	F. M. COSSITT	Method or process of coating nitrocellulose film
939,350	F. B. THOMPSON	Film-drying machine
948,731	E. A. IVATTS	Apparatus for the continuous drying of perforated kinematographic films
953,663	G. E. HOGLUND	Film drying apparatus

No.	*Inventor*	*Title*
970,972	F. B. THOMPSON	Method of coating picture films
971,889	G. E. HOGLUND	Apparatus for preparing moving picture films
1,109,208	G. C. DOBBS AND M. MCGREGOR	Apparatus for successive treatment for motion picture films
1,141,464	R. JAVAULT	Apparatus for developing and washing cinematographic films
1,143,892	V. C. YBARRONDO	Apparatus for developing films
1,150,609	J. MARETTE	Machine for drying cinematographic films and the like
1,172,074	C. C. TOWNES	Photoprint developing machine
1,233,664	P. D. BREWSTER	Apparatus for treating cinematographic films
1,260,595	F. B. THOMPSON	Film treating apparatus
1,261,056	A. J. PFOHL	Reserve feed and splicing apparatus
1,281,711	F. B. THOMPSON	Photographic film treating apparatus
1,299,266	F. B. THOMPSON	Film wiping apparatus
1,328,464	F. B. THOMPSON	Film treating apparatus
1,348,029	J. MASON	Method and apparatus for treating films
1,351,834	J. G. CAPSTAFF	Apparatus for treating motion picture films
1,361,555	H. WEISS	Photographic printing apparatus
1,403,779	F. W. HOCHSTETTER	Process and apparatus for sensitizing photographic film and paper
1,461,329	G. A. SALINS	Machine for treating cinematographic films
1,487,375	C. H. FUCHS	Wiping attachment for film drying apparatus
1,493,866	W. PARKS	Cinematograph film developing apparatus
1,527,132	F. J. M. HANSEN	Apparatus for use in the treatment of photographic film
1,543,301	F. J. J. STOCK	Method of regenerating worn cinematographic films
1,561,699	V. C. YBARRONDO	Method and apparatus for developing films
1,569,151	V. A. STEWART	Process of water-proofing motion picture films and other gelatinous surfaces
1,574,591	A. L. ADATTE	Multiple film guide mounting
1,586,710	R. W. SCOTT	Film treating and handling device
1,587,051	F. B. THOMPSON	Photographic film treating apparatus
1,591,436	G. A. SALINS	Machine for automatic coloring of films
1,607,417	W. B. WESCOTT	Squeegee apparatus
1,607,440	D. F. COMSTOCK	Cinematographic film treating apparatus
1,611,196	R. JOHN	Film drying apparatus
1,615,047	J. SHAW, *et al.*	Method of and apparatus for treating continuous films
1,616,642	L. T. TROLAND, *et al.*	Removal of superficial liquid from cinematographic films
1,623,788	C. A. HOXIE	Photographic developing apparatus
1,629,097	V. C. YBARRONDO	Apparatus for handling motion picture films
1,629,154	V. C. YBARRONDO	Pneumatic pulley for motion picture films
1,631,476	C. DEMOOS	Photographic film developing machine
1,653,451	V. C. YBARRONDO	Motion picture film developing machine

No.	*Inventor*	*Title*
1,654,723	V. C. YBARRONDO	Film developing machine having positive drive
1,666,999	F. E. GARBUTT, *et al.*	Film developing machine
1,679,096	G. POURFILLET, *et al.*	Film treating apparatus
1,682,943	W. M. THOMAS	Apparatus for treating films
1,690,616	J. G. CAPSTAFF	Film treating apparatus
1,699,349	W. B. DAILY	Method of and means for making photographic paper, film, or the like
1,707,709	D. F. COMSTOCK	Apparatus for liquid treatment of photographic films
1,723,950	F. J. MUELLER	Film handling apparatus
1,734,476	R. F. ELDER	Method of producing colored films
1,762,936	M. W. SEYMOUR	Photographic reversal process
1,810,209	G. HAYNES	Film treating machine

OPTICAL PRINTING AND TECHNIC*

LYNN DUNN**

Summary.—*The subject of optical printing is discussed with particular reference to the problems involved and the requirements for good results. After outlining the requisites of a simple printer for registration printing and straight duping, the printer used in the Camera Effects Department at the RKO Studio is described in detail. The paper concludes with a brief description of some of the special work done upon this printer.*

Optical printing, or projection printing, as it is sometimes called, is a process of rephotographing at approximately unit magnification, from one motion picture film to another. The apparatus used for this work is almost invariably specially designed and built, and consists essentially of a standard motion picture camera fitted with a registration movement, facing a printer head, likewise equipped with a registering or pilot-pin movement, and mounted upon a rigid lathe bed. With the one exception of speed of operation, this method is by far the most satisfactory of all motion picture printing methods. Full control of the original film and the raw stock is possible at all times, and the process is subject to an almost infinite degree of manipulation.

Optical printing is utilized for an endless variety of work. Duplicate negatives may be made of a positive film when the negative is not available or when a new negative is wanted; scenes that are unsatisfactory as to action or quality can often be salvaged; many shots formerly made in the camera—such as fades, dissolves, matted shots, and double-exposure or "split-screen" and composite scenes—are now made on the optical printer. Moreover, an entirely new range of trick effects, such as wipe-offs, trick transitions, and the like, have been made possible by this device. In a word, the optical printer is used to do almost everything in the line of trick photography on a duplicate negative. For that reason, it is generally re-

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** Camera Effects Dept., RKO Studios, Hollywood, Calif.

garded as the backbone of the Trick Camera Department. Regardless of whether or not a production includes any of the generally accepted forms of special effects camera work, it is certain to include a considerable footage of optically printed film. It might not be too much to say that during the past four or five years hardly a single production has been released that did not utilize the services of the optical printer to some extent.

Laboratory manipulation plays a very important part in attaining first-class quality in duping. Variation in the standard of this work is felt more by the optical printing department than by the production cinematographer, due to the fact that the quality of the dupe must match the original. It should be remembered that where in regular production cinematography, the laboratory is a factor in *three* basic steps, *i. e.*, (*1*) developing the original negative, (*2*) making the print, and (*3*) developing it; in optical printing the laboratory is a factor in no less than *five* such steps: (*1*) making the duplicating positive, (*2*) developing it, (*3*) developing the dupe negative, (*4*) making the final print from the dupe negative, and (*5*) developing the latter print. Obviously, the margin for laboratory errors is almost doubled, and successful results indicate an extremely high degree of laboratory coöperation.

Every man doing optical printing has to contend with certain definite sources of difficulty. If he can reduce the difficulties to only one, and concentrate his attention upon that one, he will find that his results will become more and more consistently satisfactory. Consistency is, of course, the most important consideration in quality optical printing. When once a satisfactory system of duping is worked out to fit the conditions and equipment at hand, the consistency of the laboratory work becomes the greatest single factor in continuously achieving good results. Granting that the printing equipment itself is first-class, from the laboratory point of view, making the lavender duping print is of the greatest importance in producing good duplicate negatives. Needless to say, without a good master print, duplication of the original negative is next to impossible. A slight variation from the proper contrast in the lavender print can be compensated in the exposure and development of the dupe negative, or by change in the duplicating raw film used. But this, of course, means variation from the set system which has been worked out, and obvious uncertainty as to the ultimate results.

To maintain the necessary consistency in the quality of the work done for a large studio, as much latitude as possible is necessary in the two major steps. These steps—making the duping print and developing the dupe negative—must have great latitude in order to accommodate any possible variations in the film, positive and negative developer, and optical printer exposure. The last factor, however, is of little consequence when one has proper checking facilities, such as a photo-cell photometer and a tachometer. It has been found that a duping print reproduces most consistently the best when made upon a soft lavender positive stock, developed normally. This print should be timed so that the highlights are printed through about two points darker than would be the case in a normal print for projection. This will still permit the blacks to be easily penetrated if the duping positive stock has the proper degree of softness. The duping negative raw stock used should then be soft enough to permit a full normal development in order to duplicate the contrast of the original negative.

It must be admitted that this duping formula is not the best for really fine-grain results; but the problem of consistency from day to day, necessary in quantity studio work, seems to be of greater importance. Due to the number of fine-grain raw films available today, the question of grain does not seem to be of as much importance as that of variation in matching the original contrast in a dupe. A dupe can be rather excessive as to graininess, but match the original well in contrast, and show a much less noticeable "jump" in quality upon the screen than if the reverse condition were true. This discussion of graininess is in reference to dissolves that are "jump cut" into the original negative. Graininess is, of course, much more objectionable when the dupe is run at any length; but under normal present-day conditions the graininess of the average properly made dupe is generally not noticeable to the general public. Much less difference can be noticed in the graininess of different duping stocks than in the results attained with different developers.

An interesting method of duping is from a duping print timed normally and developed in negative developer for about two-thirds the normal time. The dupe negative is then made on soft lavender positive stock and developed to exactly the same gamma as the duping print. This is an ideal system for fine grain, but is obviously much too critical to be followed without particularly careful laboratory supervision, so that strict consistency may be maintained. Any slight variation in either step throws the process off balance, due to the lack of latitude in the method. Obviously, there is certainly a saving in the cost of the dupe negative raw stock used in this method. However, another element that enters the question, when a radically different type of duping print such as this is used, is the fact that the optical printing department is very often called upon to dupe a stock scene received from another studio. This print is usually the more orthodox type of lavender, and it must sometimes be mixed in a series dissolve with a special type of duping print such as described above. Obviously in this case, one or the other type will suffer in reproduction. For these reasons, in studio optical printing it is unwise to stray very far from the generally accepted method of commercial quantity duping.

The subject of equipment is a difficult matter, due to the fact that very little is standard except the general layout of the camera and the printer facing each other upon a lathe bed and driven in synchronism. From a mechanical point of view the quality of the dupe depends upon three factors: (*1*) the lens; (*2*) the quality and evenness of the light; and (*3*) uniform speed. Any sharp, clean-cutting lens having an absolutely flat field can be used. A focal length of four inches is most acceptable, as that places the camera at a good workable distance from the printer head. The speed need not be faster than *f*/4.5. Aside from the regular ciné lenses, there are on the market copying lenses that are excellent for use in optical printers. A well diffused, 1000-watt, tubular projection lamp is very satisfactory for a printing light, and is strong enough to permit the lens to be used well closed down, giving improved definition. The motor should be powerful enough to drive the printer without speed fluctuation. A voltage regulator should be in the line, and the speed should be controlled by a rheostat rather than by change of pulleys or gears.

What has been said above gives some idea of the requisites of a simple printer, one that could be used for straight dupes and registration printing. As there is no standard in optical printers, every one has an individual design—usually a conglomeration of many ideas. All optical printers generally start out with the simple layout as outlined above, and are added to as the money is appropriated. If the optical printer is properly designed from the start, the additions can be made easily, and will become integral parts of the machine. This, of course, requires close coöperation between a first-class machinist-designer and the printer operator.

As a concrete example of optical printer design, the printer used in the Camera Effects Department at the RKO Studio may be described. Figs. 1 to 4 show four different views of it. With the exception of the wipe-over device, all attachments are permanent fixtures. The machine itself is one of the most modern in design, and is extremely efficient for all-around printing and trick work, operating with great ease and precision. Due to the fact that at present RKO has but one optical printer for all types of work, this machine is constantly in use. Another machine, for the simpler, straight printing, is now being completed. In addition to all straight duping, special trick matting shots, multiple-exposure work, and all other printer trick work, this machine is called upon to make all the registration prints for process-background work. This method has been the ultimate means of attaining perfect registration in the process composite. The prints are made upon the RKO machine at a printing speed of about eighteen feet per minute. The printer can run as fast as forty-two feet per minute for emergency rush work.

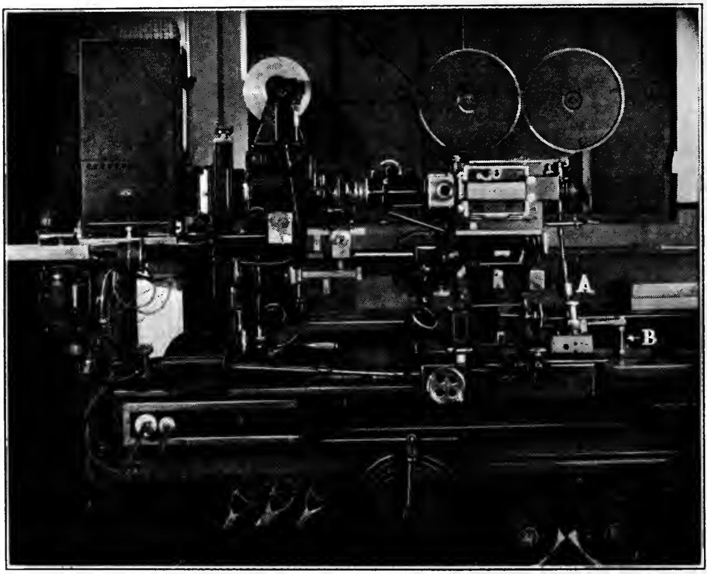

FIG. 1. Complete view of optical printer from the operating side.

Fig. 1 is a complete front view of the optical printer from the operating side. The lathe bed is six feet long, allowing for magnified shots and reduced-aperture work. The four rheostats mounted upon the lower right side of the printer are for controlling the light, printer speed, and motor rewind speed. The printer-head moves vertically, and the camera-head moves laterally. Both movements can be made by hand or motor. The camera can also be rocked mechanically.

In Fig. 2 (right end front view) the five dials are indicators for calibrating the afore-mentioned movements, graduated to 0.001 inch.

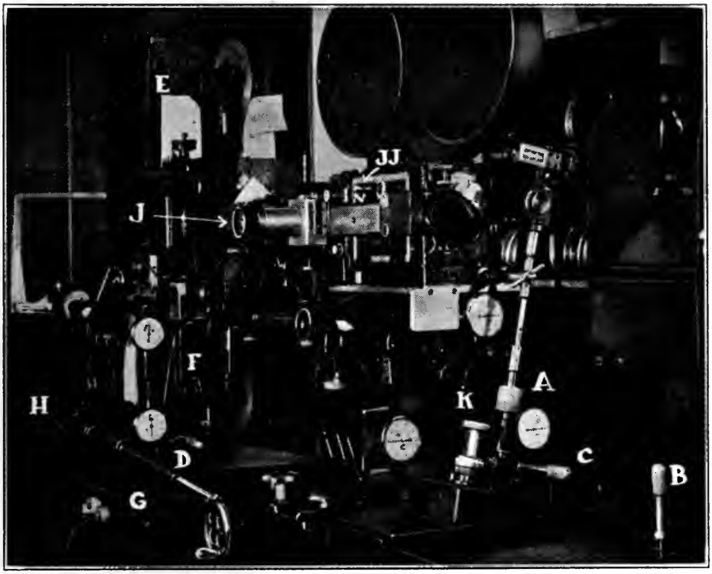

Fig. 2. Near view of the operating end of the printer.

Another of the same type of dial (not visible in the picture) is used to indicate the lens focus, which is varied by the travel of the lathe carriage. *A* is the camera drive shaft with a footage counter mounted at the top. This shaft has a gear-change for eliminating alternate frames. *B* is the motor rewind control. Film in the printer can be rewound in either direction at a speed of more than ninety feet per minute. *C* and *D* are controls to connect or disconnect the camera and the printer-head independently while in motion. The printer-head can be run in either direction. *E* and *F* are the automatic geared take-ups for the printer-head. *G* is a switchbox for most of the electrical controls, including an automatic stop. This feature causes the printer-head to stop in synchronism at any frame previously notched upon the edge. This is handy when certain frames in a scene need to be eliminated or repeated. *H* is the air-pressure control: air is piped to both sides of the movement, and just below the printer-head. The air is used to prevent "breathing" of old film, and for cleaning film entering the movement.

J is the eyepiece for an intercepting prism in back of the lens. When this prism is moved in, it throws the image upon a special ground glass showing the exact line-up of the camera aperture. This ground glass has mounted upon it a means for accurately registering a film for line-up purposes, with arrangements for moving the film along, frame by frame. In this way, any movement of the printer can be made to match a movement upon another film. *JJ* is a built-in film-punch, which places a notch four frames from the frame in the aperture. *K* is the mounting for two signal lights. The left light is a red warning light, which comes on when either camera- or printer-head is moved more than one-thousandth of an inch from its normal line-up. The other is a marker light, which comes on during a fade when the shutter reaches a predetermined opening. As the printer

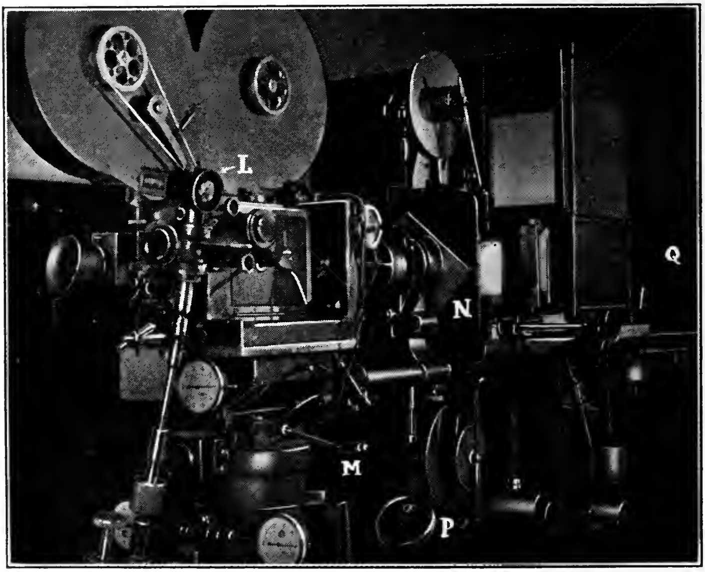

Fig. 3. Corner view, from right end of threading side.

light tests are two-foot fades, this facilitates reading the correct shutter opening for the density chosen. This same marker light, manually operated, is used to indicate the exact frame where a dissolve starts and ends, enabling the film editor to cut in his dissolves quickly and accurately.

Fig. 3 (right end rear view) shows the printer from the threading side. The counter, *L*, has a large frame-indicator, which aids in remaking dissolves any number of times to an exact length. Crank *M* operates the rocking of the printer-head. This feature is used for giving slight movement to boat and airplane interior scenes, and for other shots requiring such motions; and also for quickly levelling up certain scenes, and titles. Mounted upon rods between the two heads is the wipe-over device, *N*. Interchangeable mattes of all kinds mount upon this device, and wipes of any length can be made. Many attachments are available for making the various trick wipes called for. The ground glass window at the top of the lamp house is a handy feature for easily and accurately checking the film density. The lamp employed is of the 1000-watt, tubular projection type, the light from which is diffused by two ground glasses. The tachometer,

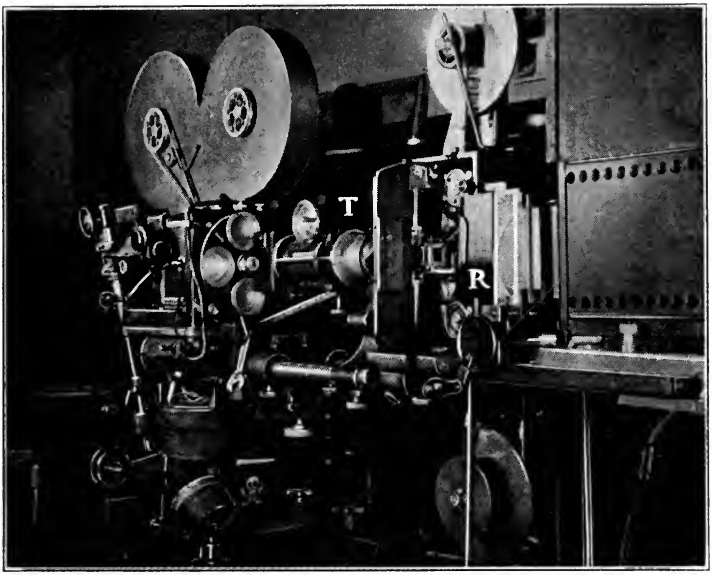

FIG. 4. View of the threading side of the printer, from the left end.

P, is for accurately checking the motor speed. At the rear end of the printer can be noticed a metal frame, *Q*. The lamp house can be readily removed, and upon this frame mounted a larger printing field which is focused upon the printer aperture. This field can be illuminated by a spot from behind, or by the reflected light of two spots from the sides, in front. Any retouching, matting, or filtering can be easily done, working to a large scale upon this printing field. Matted shots can be made in practically no more time than it takes to paint the matte. Shadows and highlights in stationary shots can be intensified or reduced with the same ease with which a retoucher works upon a still picture. Stationary or moving clouds can be doubled in scenes with great ease.

Fig. 4 (left end rear view) illustrates how the printer-head movement is mounted. The front of the movement is flush with the front of the printer-head, permitting the use of hard mattes in front of the film. The water cell, *R*, helps to reduce the heat from the lamp on the film. Behind the water cell are mounted the light-diffusing screens. The flanges shown can be easily interchanged for reels. Hand cranks are on either side of the printer-head for convenience in threading. The movement is a standard Bell & Howell pilot-pin movement, with the rear pressure-plate cut away. A special feature to be found in dupes made upon this machine is the reproduction of the original key numbers, both movements having been altered for this feature. The advantage of these key numbers to the film editor in synchronizing and cutting in the dissolves can readily be seen. The camera lens, *T*, slides into and out of its mount smoothly and without revolving, always returning exactly to its original line-up. This is an advantage for quick reducing or enlarging, and for certain zoom up and out-of-focus dissolves. At the back of the lens-mount is located the intercepting prism mentioned previously. Below the mount is the bracket holding the matte device rods. This bracket has vertical and horizontal adjustments, enabling the mattes to be slid into and out of the scene during the photographing. Although this printer may appear somewhat complicated, the important feature of it is its ease of operation, due to its special features and the accessibility of all controls. A great quantity of work can be run through it in a surprisingly short time.

It will be of interest to outline some of the special trick work done upon the optical printer. During the last few years tricky wipe-offs and intricate transitions have greatly increased in popularity. The transition, in the sense in which it is generally referred to, is an interwoven series of short impressionistic and graphic scenes. This effect has become a very popular means to pass over an important point in the story quickly and definitely, usually as a means of indicating a lapse of time. The transition is compiled upon the optical printer. A definition of the wipe-off can be "a very short mechanically effected transition from one time or place to another, used in lieu of the more conventional lap dissolve." Tricky variations of the wipe-off are usually found in musicals, comedies, and some action dramas.

Trick wipe-offs are many and varied, and are usually limited only by the ingenuity of those who devise them and the means at hand to produce them. The ultimate success of such effects depends usually upon how appropriately they are inserted into the picture. The wipe-off is most effective when carefully adapted to the action and tempo of the scenes involved. One of the first pictures to utilize the trick wipe-off throughout was a short called *So This Is Harris*. Following this came *Melody Cruise* and *Flying Down to Rio*, all these pictures employing the trick wipe-off in various forms in preference to lap dissolves.

Many odd and interesting problems present themselves to the optical printing department of a major studio. Very often the man in charge of the work is called upon to salvage a scene that is unusable, due to some unfortunate occurrence during the filming of the production. The following is a typical example of how the printer can save the studio many dollars: In filming a recent war-aviation picture a crashed plane was supposed to burst into flames just as the pilot climbed from the cockpit and reached the ground. It so happened that the plane did not flare up until the pilot had left the cockpit, reached the ground, and had crawled out of the scene. This way, the scene naturally lacked the "thrill," and was therefore counted a loss and scheduled for a retake, which involved quite an expenditure. The optical printer was given an opportunity to see what it could do to save the scene, so a test was made, dissolving to a split screen around the man at the moment he touched the ground. In this dissolve, the action of the plane was moved ahead about twenty feet to the point at which it burst into flames, thus eliminating the dead footage. However, the area that included the man's action continued on normally, the split screen being made with a soft blend that was imperceptible.

Another example of a simple job that saved much money occurred in a recent picture in which an oil-truck moving into an important scene had an objectionable name upon it. By means of a fine grease pencil mark placed upon a glass in front of the optical printer aperture, the name was slightly blurred, enough to prevent its being recognized. The glass was slid along frame by frame to match the movement of the truck.

Jobs of this type present themselves regularly, and prove more and more the importance of the optical printer to modern motion picture making. What the future holds for this branch of trick cinematography is hard to predict, but as studio executives become more and more familiar with its limitless artistic and money-saving possibilities, as briefly outlined here, it is certain that they will take more interest in this branch of their Camera Effects Department.

(*A reel of film was projected, showing an assortment of optical printer effects from past RKO pictures, in order to afford an idea of the work that can be done on the device described above.*)

DISCUSSION

MR. CRABTREE: What is the slowest printing speed that you would be willing to tolerate?

MR. DUNN: The average speed is about 20 feet per minute, and the slowest speed we should want to tolerate would be about six feet per minute.

MR. CRABTREE: We all know that definition greatly influences the graininess of the result in duping. In other words, if the image is thrown very slightly out of focus, the graininess is greatly diminished. I was wondering whether you deliberately throw it out of focus, or whether you aim at the ultimate in definition in making the dupes?

MR. DUNN: We aim at the ultimate in definition—just as sharp as we can possibly get the dupe. One of the main reasons is that if a dissolve were made slightly out of focus to reduce the graininess, there would be a noticeable jump when it was cut into the original. Definition is very important, and what definition loss you see is due partly to the graininess and partly to the optical system.

MR. CRABTREE: Do you recommend making the lavender to a lower degree of contrast than the average positive print, or to a higher degree of contrast?

MR. DUNN: There are different practices in Hollywood. Some studios use a lavender of higher than normal gamma, and some use lower. It usually depends a lot upon the set-up of the equipment, the quality of the lens, and the laboratory facilities at hand. We find that using a softer lavender and a softer negative duping stock affords more latitude to the duping process, and when a quantity of work is run through all the time, the latitude is very important.

MR. CRABTREE: The softer you develop your lavender, of course, the greater must be the contrast of the negative?

MR. DUNN: The contrast is built up by the optical printer. The light transmission builds up the contrast to a much greater degree than in contact printing.

It is built up to such a degree that really our greatest difficulty is that it generally varies to a higher gamma rather than a lower.

MR. CRABTREE: Do you print from the lavender print on the optical printer? Also, at what stage do you put your trick stuff in—when making the lavender print from the original negative, or when making the dupe negative from the lavender?

MR. DUNN: That depends entirely upon the trick effect that is to be made. Some effects necessitate work upon the lavender at the time it is made from the original negative, and then again when the lavender is photographed, depending upon whether we have to work with a positive or a negative. In other words, if we have to block out while printing the original negative, the results naturally will be clear film; and if we block out while photographing the lavender, the results will be black. So it depends upon the type of effect needed. In most cases, it is during the last step, photographing the lavender.

MR. DEPUE: How was the trick effect accomplished in the demonstration reel when the picture folded off or folded down?

MR. DUNN: That is an effect that we have made only once. Some of the effects are brainstorms, and one has to go almost into a trance to make them; and after they are finished it is hard to tell just how they were done. That effect was done with a single frame. Although some of you might have noticed that that was a single frame, I do not believe that the average public would. The scene following the effect is blocked out to fit the first scene's frame sliding out. In other words, it is matted out to conform to the positions of the frame as it will slide out. Then that frame is put into a special holder and lined up to normal position, and slid out mechanically, synchronized with the previous matting. It happens, I believe, in about a foot and a half of film, so the single frame does not seem to be noticeable in most cases.

MR. CRABTREE: Assuming that you print both the lavender and the dupe negative in the optical printer as you have indicated, you have a choice of two procedures: first, to develop the lavender to a high gamma and the negative to a relatively low gamma; or, second, to develop the lavender to a medium gamma and the negative to a higher gamma than in the first case. Of those two procedures which do you prefer?

MR. DUNN: We don't employ either procedure. The procedure we employ is not, as I said in the paper, entirely desirable, but we have to use it on account of the consistency and the quantity of work, and the rush with which it has to be gotten out. We make our lavender to a lower gamma than in an ordinary projection print, and develop the negative to a lower gamma than normal. So it is really softer on both ends, the contrast being built up by the optical printer. The ordinary production positive gamma, we might say, as used at RKO, is about 2.20 or 2.30, and our lavender goes to 1.70. The original negative is developed to, I believe, 0.68 and our dupe negative to about 0.55, so that the gamma is lower than normal on both ends. That is really a feature that is not entirely desirable, but the optical printer builds up so much contrast that it is necessary.

MR. CRABTREE: With regard to definition, it is of extreme importance when making comparisons to focus the image repeatedly upon the screen. You have to have a telescope at the projector and continuously focus the image in order to make really worth-while comparisons with regard to graininess.

MR. DUNN: That is right.

MR. CRABTREE: Does the laboratory develop the lavender and the dupe negative for you separately, or do they like to run the negative, for instance, with the regular run of negatives, and the lavender with the regular run of positives?

MR. DUNN: They like to do it in the simplest way, naturally; and we find that the simpler we can make it for the laboratory, the less trouble we have, unless the laboratory is right under our control, which it is not, in our case. For consistency and evenness I have tried to adjust my system so that the lavender develops the same speed as the ordinary daily production print, and the dupe negative develops the same speed as the production negative. As I said in the paper, that is not quite desirable, but we get better general results and greater consistency.

To do this naturally necessitated quite a lot of experimentation with various raw stocks in order to make them fit the conditions. As we were working to a certain developing time, the only factor that we could vary was the type of raw stock, and we have arrived at a raw stock combination that is quite satisfactory. It seems that we can not use any other as successfully, but I have tested other stocks, and have found that we were using a pretty good set-up as far as stock graininess is concerned.

The only thing that would improve our graininess considerably would be to use a special developer, paraphenylene, for example, for negative development.

MR. CRABTREE: That is why I asked the question as to the minimum speed that you would tolerate. I suppose if you could get results, probably you would go down to one frame a second, perhaps?

MR. DUNN: No, we should not, because we have the studio problem to take into consideration. We should not be able to get the work out in time.

MR. KIENNINGER: How close do you place the diffusion to the negative?

MR. DUNN: About eight inches, I should say, back of the negative. It is well clear of the negative, so that it can be any kind of ground glass, coarse or fine.

MR. KIENNINGER: Do you have to go back that far?

MR. DUNN: No, we do not have to, but we have not found any reason to come closer, and it gives us more room to thread the printer and put in mattes.

MR. KIENNINGER: What is your optical printer factor or gamma compared with the contact printer gamma?

MR. DUNN: About the difference between 3.0 and 1.5. I should say it would almost double the contrast.

WIDE-RANGE REPRODUCTION IN THEATERS*

J. P. MAXFIELD AND C. FLANNAGAN**

Summary.—*The problem of wide-range reproduction in theaters is discussed with reference to the amplifier output power capacity; the importance of accurate adjustment of equipment; special installation technic; acoustic diagnosis for positioning of high-frequency, mid-range, and low-frequency units; volume setting; and diagnosis of acoustic treatment of backstage interference.*

The purpose of any sound reproducing system in a theater is to enable the sound portion of a talking picture to be reproduced in such a manner that the full dramatic effects desired may be produced in the audience. In the early days of sound pictures there were two distinct limitations that prevented the system from completely fulfilling this requirement: first, a limited frequency range; and, second, a limited loudness or volume range. While there were, of course, other forms of distortion present they were, in most instances, of less commercial importance than the two just mentioned. From an engineering standpoint these older systems might have been termed "restricted-range systems."

In contrast to these are the "wide-range" systems with which this paper deals and in which both frequency and volume ranges have been very considerably increased. We feel that we now have a system, the range of which is adequate to reproduce all the qualities of the human voice and falls much less short of complete reproduction of an orchestra than did the older systems.

It is obvious that an effective extension of the volume and frequency range provides the picture director with a tool that will greatly assist him in bringing out inflections and qualities of the voice that were before largely, if not entirely, lost. Likewise, the extension of the volume range provides him with a means for achieving dramatic effects which before could be only approximated.

With reference to the extension of the frequency range, the data

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Electrical Research Products, Inc., New York, N. Y.

usually presented take the form of a steady-state frequency characteristic. Attainment of a satisfactory curve of this kind is, however, not the only requirement, and it might be interesting to point out some of the factors that are important to good performance. While it is certainly requisite that all the components of each sound shall be reproduced in their correct amplitudes, it is also desirable that the sound shall be reproduced with the right duration. Resonant elements introduce transients, recognized as a prolongation of some sounds beyond their natural duration, so that they overlap the following sounds, thus distorting quality. In the present advanced state of the art this is not often so in the electrical design. Such prolongation occurs occasionally in the case of loud speakers of inadequate design and frequently in auditoriums where the backstage area permits marked standing-wave patterns. Such effects impair the performance of the best sound systems.

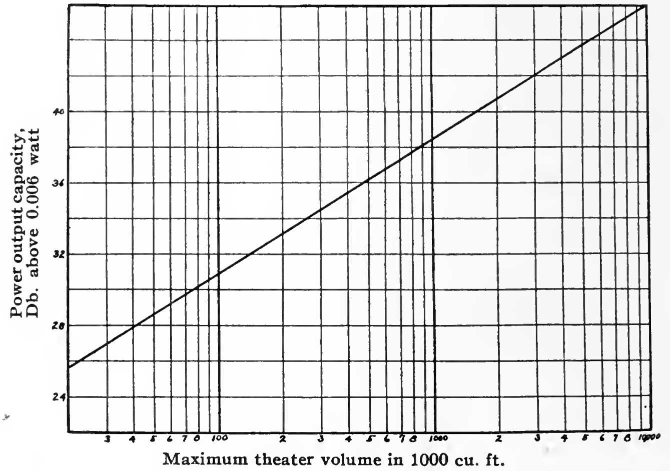

FIG. 1. Relation between capacity of amplifier and size of auditorium.

A further requirement of the system is that there be no non-linear distortion, which distortion is evidenced by the introduction of components that are not present in the original sound. In other words, there must be a linear relationship between the amplitude of the input and that of the output in all parts of the system.

AMPLIFIER OUTPUT POWER CAPACITY

This leads naturally to a consideration of the power output of the amplifier necessary to supply auditoriums of various sizes. A considerable amount of work[1,2] has been done along this line which makes it possible to set the amplifier requirements rather definitely. Fig. 1 shows a curve, the ordinates of which represent the power output capacity of the amplifier and the abscissas of which represent the cubical contents of the largest auditorium for which this amplifier is regarded as commercially satisfactory with the present loud speakers.

The question of the power required for wide-range reproduction is rather interesting. If a system already installed be modified to permit wide-range reproduction without consideration of the amplifier power capacity, well recorded music will sound slightly louder than it does on the standard system. On the other hand, the improvement in naturalness, brought about by extending the range, leads one to feel that he is listening to the orchestra itself rather than a reproduction of it, and the immediate reaction is a feeling that the loudness is insufficient. It is interesting that this improvement in quality appears to transfer the mind of the listener from an artificial standard to the standard of the real original performance. In view of this effect, it has been found desirable to increase the power capacity available for the wide-range system as compared with the old standard system. In theaters already equipped with systems of the old type, observations were made to determine the adequacy of existing amplifiers before the wide-range modification. It was found desirable in many cases to modify or replace the amplifiers to insure conformance with the requirements shown in Fig. 1. In theaters not previously wired for sound, higher powered amplifiers than would normally be employed in restricted-range systems were installed.

Wide-range systems appear to have sufficient power to reproduce adequately anything now recorded upon, or likely to be recorded upon, film in the near future. Whether or not they have sufficient reserve to meet any future demand is, of course, impossible to foretell accurately.

IMPORTANCE OF ACCURATE ADJUSTMENT OF EQUIPMENT

In order to attain the greatest dramatic effect from this improved equipment, it has been necessary to develop a very definite technic of installation. The procedure is of importance, first, in coördinating the operation of the various parts of the equipment, one with another; and, second, in acoustically draping the backstage space to avoid standing-wave interferences.

As a preliminary to the description of this procedure, a brief statement regarding the equipment may be of interest. The equipment consists, essentially, of the sound-head for translating the sound-track into electrical impulses, an amplifier system to amplify these weak impulses, and a loud speaker system to translate the electric currents back into sound. The main part of the description will deal with the loud speaker equipment, although it has been necessary to make improvements in all parts of the system in order that it may be capable of transmitting to the loud speakers the increased volume and frequency range.

The loud speaker system differs materially from the earlier commercial theater types mainly in that there are three sets of loud speakers, one for the low frequencies, one for the mid-range, and one for the extremely high frequencies. In addition to these three sets of speakers, a network is necessary for splitting the output current of the amplifier into three frequency-bands, one for each set of loud speakers. The ranges covered by these three sets of loud speakers are approximately as follows:

Low-frequency set	Up to 300 cycles
Mid-range set	300 to about 3000 cycles
High-frequency set	3000 cycles and up

It will be seen from a consideration of this type of system that a definite problem is found in arranging the system to avoid bad interference within the frequency ranges in which the various sets of loud speakers overlap. This is particularly true because the electrical network that divides the amplifier output into the three frequency-bands is not of the sharp cut-off type, and therefore permits considerable overlapping of the various sets of speakers. The sharpness of this cut-off, in a commercial system, is of necessity a compromise between expense and effectiveness. The sharpness afforded by this system has been found adequate for good quality provided the proper installation procedure is followed.

SPECIAL INSTALLATION TECHNIC—GENERAL

The special installation technic is carried out for the purpose of insuring that the various parts of the reproducing equipment co-operate properly with one another. This technic has naturally divided itself into the following series of operations:

(1) Acoustic diagnosis of theater auditorium.
(2) Positioning the mid-range horns to afford best sound distribution.
(3) Positioning and volume setting of the low-frequency units.
(4) Diagnosis and acoustic treatment of backstage interferences.
(5) Positioning and volume setting of high-frequency units.
(6) Final check of system on commercial product.

ACOUSTIC DIAGNOSIS OF THEATER AUDITORIUM

If expense were no object, the acoustic diagnosis would be made with measuring instruments, many of which have been described in the literature.[3] However, it is frequently impracticable to make the necessary measurements, and under such conditions the reverberation time and its frequency characteristic are computed from a survey of the size and shape of the auditorium and from the nature of the floor, walls, seats, hangings, *etc.* This reverberation time becomes the starting point of the theater analysis.

In the application of the wide-range systems to the theater, there are other acoustic properties besides the average reverberation time which are of great importance. Again, for practical reasons, these effects have been divided into two groups: those caused by the frontstage sound in the auditorium and those caused by the conditions backstage. All discussion of the backstage troubles will be left to a later portion of the paper, and the present discussion will deal only with the frontstage effects.

These special effects refer to concentrated reflections from large, flat, or curved surfaces, such as the back wall, a curved ceiling or dome, the front of a deep balcony, *etc.* As is well known,[4] the reverberation time for satisfactory reproduction lies between two limits which are rather widely separated. In practice, very few houses, if any, are found to be too dead. Therefore, it has been customary to specify these limits as the time of reverberation for optimal reproduction and as the maximal time of reverberation acceptable for commercially good quality. In addition to determining the reverberation time, which is an index of general liveness, the acoustic analysis determines the presence of echoes, "slaps," multiple reflections, *etc.*, from undamped, curved, flat surfaces. In theaters having such defects, which have not been corrected by acoustic treatment, careful diagnosis by ear, after the system has been installed, frequently permits positioning the loud speakers to minimize the defects. Such diagnosis consists in exploring the whole audience area by ear while reproducing some form of speech with the loud speakers on the stage. It has been found possible, under these conditions, to locate the so-called "slap" or echo areas; and, in most cases, a visual inspection of the position of the sound-source, the slap area, and the geometry of the house leads immediately to detecting the sound path causing the difficulty. However, a considerable amount of skill is involved.

POSITIONING MID-RANGE HORNS

The next step of the procedure, therefore, is to position the mid-range, or horn, speakers in such a manner that their sound is distributed to the audience area without bad interference from echoes and slaps. In the majority of houses, the reverberation time of which lies within acceptable limits, this is possible without additional acoustic treatment Since the horn speakers are directional to a large degree, it is possible to direct the sound into the audience area in such a manner that very little direct sound from the horns reaches the troublesome reflecting areas. Naturally, in the case of a curved back wall, it is necessary either to sacrifice good sound in some of the back seats or to apply acoustic treatment to the wall immediately above the heads of the audience.

Since the majority of theaters have a higher reverberation time than optimal, and are, therefore, livelier than desirable, the technic of avoiding "slap" by concentrating the sound upon the audience area has automatically introduced an improvement, namely, an apparent decrease in the reverberation of the house. Because the ear interprets the liveness of a reproduction by the ratio of the time integral of the reverberant sound to the intensity of the direct sound,[5] any means of increasing the direct sound or of decreasing the reverberant sound tends to decrease the liveness. By concentrating the direct sound from the horns upon the audience area, a maximum of direct sound is attained at the listener's ear. In addition, since the audience usually constitutes the most effective damping in the theater, the reflected sound that finally reaches the livelier part of the theater, to become reverberation, is thereby decreased. For both these reasons, therefore, a house can be made to appear under reproducing conditions, deader than it would be for a real performance for which most of the sound sources are relatively non-directional. This is one of the reasons why the maximal acceptable time of reverberation is as high as it is for reproduced speech.

One interesting effect has been noticed in connection with setting the horns, namely, that a much more accurate setting can be obtained by so positioning them, initially, that they definitely include the error to be avoided. They are then angled or moved slightly until this error disappears. This implies that the ear can more accurately determine the removal of an error than the approach to it. Whether this would be true if the recording and its reproduction were perfect is not known, but it is certainly true under the present practical conditions.

POSITIONING AND VOLUME SETTING OF LOW-FREQUENCY UNITS

Now that the horns have been properly set, the next step of the procedure is the addition of the low-frequency units. Early in the wide-range work a phase relationship was looked for between the lower-frequency and mid-range units, and an effect was found that was mistaken for a real phase relationship. Later work, however, indicated that this effect had many properties that did not agree with real vector phasing, and the exact nature of the effect is not completely known. The presence of real vector phasing is audible, but the slight change of quality brought about by it is neither disagreeable nor is it noticeable to the majority of the public. On the other hand, the important effect, that is, the one previously mistaken for real phasing, produces a marked difference in quality according to the correctness or incorrectness of the geometrical and electrical relations between the mid-range and the low-frequency units. The effect of improper relationship is easily noticed, and is disliked by the majority of the public. In the so-called unphased conditions, the sound is distinctly disagreeable; whereas in the so-called phased position, it is said by the layman to be pleasing to listen to.

It has been found that for a horn of a given length there are a series of fore and aft positions at which the baffle may be placed for good quality. This is on the assumption that the mid-range and the low-frequency units are electrically poled identically; that is, that the current supplied to them produces, in both sets of units, movements of the diaphragms in the same direction. If the polarity of either set of units be reversed, a new series of positions are found for the baffle half-way between the points lying upon the previously mentioned series. It is no wonder, therefore, that this effect was mistaken at first for vector phasing.

In the early technic, loud speakers were set to reproduce correctly for a point on the floor of the house, and the balcony was regarded as of secondary importance. However, in several installations where two observers were available, one was placed in the balcony and one on the floor of the house. It was surprising to find that both these observers chose the same phasing positions in spite of the fact that in some cases the observer in the balcony should have been in a position 180 degrees out of phase with the position of the observer on the floor. In other words, this effect is not a real sound-vector phasing effect, but appears to have something to do with the diffraction pattern set up about the top edge of the baffle and the bottom edge of the horn. This is further corroborated by the fact that the so-called phasing position is independent of the vertical distance between the lower edge of the horn mouth and the top edge of the baffle.

DIAGNOSIS AND ACOUSTIC TREATMENT OF BACKSTAGE INTERFERENCES

The backstage acoustic difficulties are brought about mainly by the radiation from the back of the low-frequency units and by the mid-range sound reflected into the backstage area by the screen. This sound is reflected from the various walls of the backstage area, and some of it returns to the units in such phase relation as to add to the sound then being radiated. Under these conditions marked standing-wave patterns are set up. The commonest, and usually the most marked, of these patterns is that existing between the low-frequency units and the rear stage wall. In order to minimize this pattern the baffle is usually inclined slightly with respect to the vertical in such a manner that the sound returning from the back wall and striking the baffle is reflected slightly upward, thereby avoiding a sharp standing-wave pattern between two hard, parallel surfaces. In spite of this precaution, a rather severe pattern is usually set up, and acoustic absorption material is necessary to counteract its bad effects.

It is well known[6] that acoustic damping material is most effective in a standing-wave pattern at the position where the air particle velocity is greatest. This position on the wave is the position of minimal sound to the ear, since the maximal velocity position is the position of minimal pressure variation.

In order to diagnose the position of this velocity maximum it is necessary only to move the head slowly from the back wall to the baffle while the system is reproducing male speech. During this procedure the positions are noted at which the so-called "boominess" of the sound is least. These positions of least "boominess" are the points at which damping material will be most effective. From a commercial standpoint it is fortunate that the minimum nearest the baffle is usually the sharpest one, and, therefore, constitutes the most effective position for the draping material.

The draping material used is unimportant, provided that it is soft and flexible and has an absorption equivalent to Ozite, $^1/_4$ to $^1/_2$ inch thick. Two thicknesses of heavy velour spaced one inch apart have been found quite satisfactory.

Having found the proper position for the drape, which is usually called the main drape, it is hung immediately. It is now necessary again to explore the backstage for additional standing-wave patterns which sometimes arise between the low-frequency units and the side-walls or between the low-frequency units and the ceiling. With the main drapes in place, it is occasionally found that the sound, as heard in the auditorium, either lacks "presence," that is, appears to come from some distance behind the screen, or that it seems as if considerable non-linear distortion were present. Under these circumstances it is necessary to explore the backstage area, particularly the region between the bottom of the horn mouths and the top of the baffle, for the presence of patterns. This is done, as in the previous case, by moving the head slowly about in this area while speech is being reproduced. In this case, instead of getting sharp maxima and minima of intensity, a condition is found in which the head moves from a region of badly garbled speech to one of relatively clean, clear, intelligible speech. As before, drapes should be hung at the position of least garbling; in other words, at the position of maximal clarity.

The importance of careful backstage draping can not be too vigorously stressed, because most of the troubles of the early installations of wide-range systems were brought about by complicated backstage patterns. These troubles were mainly removed when this pattern was properly diagnosed and the necessary drapes hung.

POSITIONING AND VOLUME SETTING OF HIGH-FREQUENCY UNITS

It will be seen that up to this point the system has been operated without the high-frequency units, and that it is ready for commercial use except for the addition of these units. It has been found by experience that the positioning technic for these is similar to that for the baffle with respect to the mid-range units. The positioning of the high-frequency units is of great importance as regards the quality that will be obtained from the system. The high-frequency units show a definite series of fore and aft positions, with respect to the mouth of the mid-range horns, at which the sound quality is pleasing. If the polarity of the high-frequency units be reversed, a new series of positions are found lying half-way between the positions of the first series. This is a rather startling result, because the air-path difference to the screen from the diaphragm of the mid-range units and from the diaphragm of the high-frequency units is frequently as great as fourteen feet. This distance corresponds roughly to forty times the distance between the positions at which the high-frequency units sound good. Since the dividing network is not of the sharp cutoff variety, there is considerable overlap between the mid-range and high-frequency units and it is readily seen that this positioning effect can not possibly be real vector phasing.

Having positioned the high-frequency units by ear during the reproduction of an adequate test-film, the only remaining step is to regulate their intensities so that they blend properly with the rest of the reproduction. With this done, a final check is made with the commercial product available in the theater.

RÉSUMÉ OF EXPERIENCE UNDER WIDELY VARYING FIELD CONDITIONS

Reproducing equipment designed and installed to fulfill the foregoing requirements has been in use in more than twelve hundred theaters. In some theaters it has been in operation for over two years. As would be expected in a theater group of such size, practically all types of auditoriums are represented. Under these circumstances the problem of attaining and maintaining optimal performance through installation and service of the equipment has been of much importance.

The equipment, as developed and installed, has proved itself very flexible under these varied practical conditions of field operation. It has been possible to use the system in houses of widely varying acoustic properties and to achieve in these houses the full dramatic possibilities of which the equipment is capable. This, of course, does not mean that all the houses have been found satisfactory without the help of acoustic treatment. On the other hand, it does mean that many houses, which, on the basis of the old system, were regarded as very difficult acoustically, have been successfully equipped with the wide-range system with no acoustic treatment of the auditorium.

The adoption of this installation technic has produced in the theaters a quality varying between narrow limits from one theater to another. This should be of material assistance to the recording directors who have to make products to be played in theaters throughout the country.

Although the average releases do not include material that completely shows the capabilities of wide-range systems, there are some that do, and a steady improvement in this respect is rapidly becoming general. As this is written, releases are being shown that can not be presented to full advantage on restricted-range systems.

Exhibitors are aware of the superiority of wide-range systems as is evidenced by their willingness to install new equipment even in these times of low box-office receipts. The public is only partially aware of it, but is gradually appreciating those theaters that provide better dramatic value in their sound. This appreciation will, of course, be accelerated as the sound quality of the average release is improved and the picture director takes greater advantage of the dramatic possibilities available to him.

REFERENCES

[1] WOLF, S. K., AND SETTE, W. J.: "Acoustic Power Levels in Sound Picture Reproduction," *J. Acoust. Soc. Amer.*, **2** (Jan., 1931), No. 3. p. 384.

[2] FLETCHER, H.: "Auditory Perspective—Basic Requirements," *Electrical Engineering*, **53** (Jan., 1934), No. 1, p. 9.

[3] STANTON, G. T., SCHMID, F. C., AND BROWN, W. J.: "Reverberation Measurements in Auditoriums," *J. Acoust. Soc. Amer.*, **6** (Oct., 1934), No. 2, p. 95.

[4] WATSON, F. R.: "Acoustics of Buildings," *John Wiley & Sons*, New York (1923).

[5] ALBERSHEIM, W. J., AND MAXFIELD, J. P.: "An Acoustic Constant of Enclosed Spaces Correlatable with Their Apparent Liveness," *Meeting of Acoust. Soc. Amer.* (May, 1932).

[6] SABINE, W. C.: "Collected Papers on Acoustics," *Harvard Univ. Press*, 1927.

DISCUSSION

MR. TIMMER: What is the frequency range for the three units?

MR. MAXFIELD: The lowest frequency is about 55 cycles per second, and the highest one is somewhere above 10,000, so far as the horns themselves are concerned. The modern amplifiers fulfill that requirement.

MR. SETMEIRER: In the Journal of the Acoustical Society, Eiker and Strutt report increases in loudness where the reproducing units have characteristics differing in level by as much as 12 db. Have you come across any relations similar to that in the overlapping of the characteristics of the various horns?

MR. MAXFIELD: No. In general, the addition of the bass has increased the loudness by about what would be expected on an energy-addition basis. I read with some interest the paper of Eiker and Strutt, and made a rough check with some of our theater systems. We did not find the unexpected increase that they mentioned. However, Eiker and Strutt used loud speakers widely separated in space, whereas in the theater system described that is not the case.

MR. KELLOGG: In the discussion at the Acoustical Society meeting, Dr. Strutt and others concluded that it was necessary that the loud speakers be separated, but we could find no justification for that in tests that were run at Camden. Dr. Fletcher cited the following example, which seemed to me to explain what Eiker and Strutt reported: If the entire spectrum of music or speech is cut in two, with low-pass and high-pass filters, at such a point that the total loudness contributed by each part is about equal to that of the other, then, when the two are put together, the loudness of the combination is about 9 db. greater than that of either half alone. That being true, I should expect that the addition of the bass unit, of which Mr. Maxfield spoke, would contribute in the combination more volume than we should judge it would by hearing the bass alone.

MR. MAXFIELD: As I said before, the filter or split circuit is not a sharp cut-off filter, nor in the old systems were the low frequencies completely missing. They were merely down in intensity, as compared with the higher ones. I do not believe we are dealing here with quite the situation that applies in the Strutt paper, or in the experiment that Fletcher discussed. Fletcher was using sharp cut-off filters, and I believe that is the reason why he found a much greater effect than we do. I believe we have found a small difference occasionally, but we never had the measuring instruments with us in the theater to make a careful quantitative check.

MR. BROCKWAY: Is the tendency of the recording reverberation in the film to cut down the optimal reverberation time in the theaters, or does that become noticeable at all?

MR. MAXFIELD: That is rather a long story, but we have found in connection with recording reverberation that the greater the liveliness of the theater in which the sound is to be reproduced, the more reverberation should be recorded in the original sound. In other words, it is a question of making the reproduction appear to be an extension of the auditorium in which one is listening, and the extension should appear to exist immediately behind the screen, *i. e.*, in the space that is imagined to be filled by the three dimensions of the picture.

Fortunately, the "liveness" range of the houses that are acceptable from an intelligibility standpoint is sufficiently narrow so that a single average of recording can be made which will take care of the majority of the houses satisfactorily.

AN INVESTIGATION OF SOURCES OF DIRECT CURRENT FOR THE NON-ROTATING HIGH-INTENSITY REFLECTING ARC*

C. C. DASH**

Summary.—*Results of investigations on sources of direct current for the non-rotating, high-intensity reflecting arc are presented. Data are given on the operating characteristics, including efficiency and power-factor.*

The introduction of the non-rotating, high-intensity reflecting arc has presented a problem to the electrical manufacturers in the production of a satisfactory source of direct current for use with this arc. Its operating characteristics, which have been discussed in earlier papers, are quite different from those of the previous types used in motion picture projection. The new arc is much more susceptible to changes of voltage in the d-c. source than the old arc, and hence must be handled more carefully, and more precautions must be taken in selecting the current supply equipment.

(*A*) D-c. power service from central station
(*B*) A-c. to d-c. converting equipment
    (*1*) Non-rotating equipment:
        (*a*) Hot cathode tube rectifiers
        (*b*) Copper-oxide rectifiers
    (*2*) Rotating equipment:
        (*a*) Synchronous converters
        (*b*) Motor-generator sets
            (1) Generator for each lamp, drooping characteristic, no ballast
            (2) Generator, flat-compounded using ballast

A. DIRECT-CURRENT LINE SERVICE

When d-c. service is obtained from a central station the auxiliary equipment used with the arc need be only properly designed ballast rheostats having a sufficient voltage drop to limit the current to the proper value at the correct arc voltage. In the average theater

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Hertner Electric Co., Cleveland, Ohio.

installation the voltage delivered by the central station usually increases at about nine o'clock in the evening and it is necessary to have some easily operated regulating device upon the ballast rheostat so that the resistance can be changed in order to compensate for this increase in supply voltage. When considering the over-all efficiency of using direct current from a central station, it must be borne in mind that the cost per kilowatt hour for direct current from such a source is usually much higher than that paid per unit when the power is obtained from a-c. mains.

For an arc voltage of 35 volts and a current of 50 amperes, the total power drawn from the d-c. line at 115 volts is 5750 watts, of which 1750 would be utilized in the lamp and 4000 consumed in the ballast resistance in the form of heat. The over-all efficiency, therefore, is 30.4 per cent. The inrush of current when the arc is struck, using this form of supply, is but very little greater than the normal operating value, and does not exceed ten to fifteen per cent more than the normal operating current.

The power equipment in the central station or in a central system usually consists of a multiplicity of types and sizes of generators. In some instances storage batteries are floated across the d-c. line, so that there is practically no ripple and the current is practically true direct current. As the noise in an arc is a function of the ripple in the d-c. supply, and inasmuch as there is no ripple with such an arrangement, there is practically no hum in the arc.

The current through the arc is very steady, due to the large ballast drop, but the results attained with a meter for measuring the steadiness of the light indicate considerable variation of the luminous intensity upon the screen due to the fact that the arc voltage can vary considerably without a compensating change in the current, and thereby affect the light output. The operating characteristic when working on the d-c. power line is not important to the operator as long as the power source remains steady and the voltage does not fluctuate suddenly.

B. A-C. TO D-C. CONVERTING EQUIPMENT

Non-Rotating Equipment

(*a*) *Hot Cathode Tube Rectifier.*—The hot cathode tube rectifier uses no ballast resistance between the tube and the lamp. These rectifiers are made to operate from three- or two-phase supplies, and may be operated on single phase. The over-all efficiency of a hot cathode tube rectifier that was tested, using an arc voltage of 35 and an arc current of 50 amperes, was 65.5 per cent. The power-factor when supplying the above-mentioned load was 65.6 per cent. The inrush of current when the arc was struck varied between 75 and 95 amperes, or an average of 85 amperes for the 50-ampere arc. These readings were taken with an aperiodic meter. The volt-ampere performance of this type of rectifier is shown in Fig. 1.

The ripple in the direct current produced by the rectifier has a frequency of 240 cycles, the transformers being connected in the open delta arrangement. The rms. voltage of the ripple when the rectifier delivers 50 amperes at 35 volts is 4.25. When operating without load, the rms. voltage of the ripple is 14.5. The result is that the ripple produces noise in the arc of such frequency that it may cause interference.

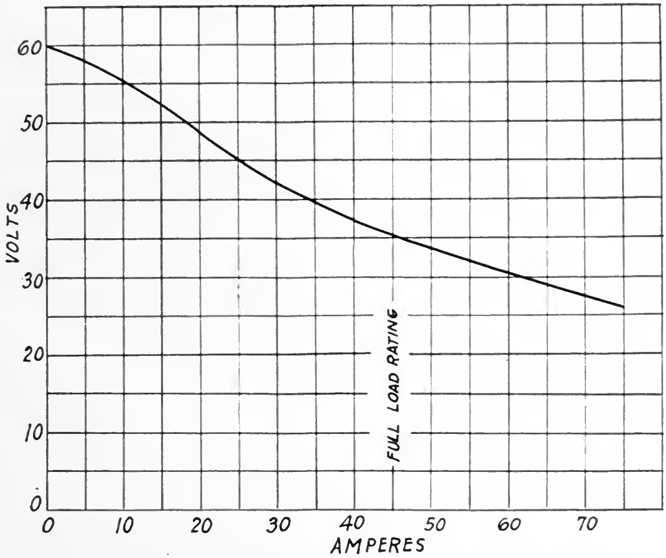

Fig. 1. Volt-ampere characteristic of the hot cathode tube rectifier.

The current in the arc varies between 46 and 60 amperes when the rectifier is adjusted to supply 50 amperes at 35 volts. Part of this change is due to the characteristic of the arc, but most of it is due to fluctuations in the a-c. line voltage. In the hot cathode tube rectifier, the d-c. output is magnetically connected to the a-c. input so that fluctuations in the a-c. line voltage are carried directly through the rectifier, causing magnified fluctuations in the screen illumination. In the case of gradual changes of the a-c. voltage, correction can be made by changing the taps on the rectifier transformer; but when the changes occur suddenly they can not be compensated for; and when the voltage increases, the tubes and the carbons become overloaded, resulting in decreased tube life as well as increased carbon consumption and a flare upon the screen.

The question of tube life is very uncertain. The average estimated life is 1000 hours, so that figures applying to the operating cost of the hot cathode rectifier should include the tube cost in order that they may be on a comparable basis with the costs of other types of equipment. If the arc is not properly handled, a surge may occur and damage the tube.

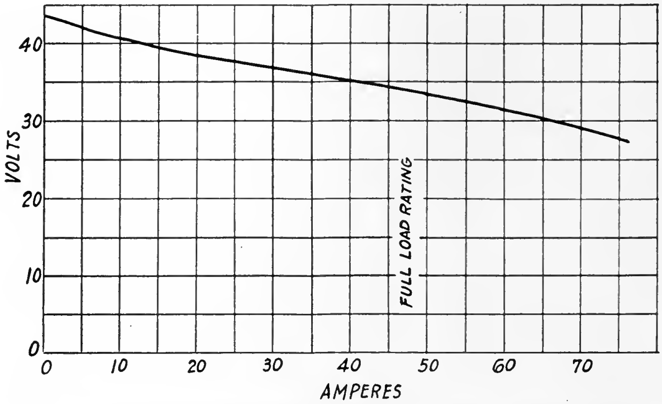

FIG. 2. Volt-ampere characteristic of the copper-oxide rectifier.

(*b*) *Copper-Oxide Rectifier.*—The copper-oxide rectifier recently placed upon the market also operates without any ballast resistance between the rectifier and the arc. The over-all efficiency of a copper-oxide rectifier that was tested, supplying a 50-ampere arc at 35 volts, was 65.5 per cent, including the fan and relay losses. The power-factor when supplying a normal load was 93.6 per cent; and the inrush of current when the arc was struck, using the same equipment as was used in former tests of this nature, averaged 95 amperes.

Fig. 2 shows the volt-ampere characteristic of the copper-oxide rectifier. The rms. ripple voltage is 1.2 volts, the frequency in this case being 360 cycles. The ripple causes considerable noise in the arc, but it is difficult to give any comparative values of the noise with the two types of rectifiers. The observations showed that this arc was not as noisy as the arc produced by direct current supplied by the hot cathode rectifier. In operation, the arc current and voltage seemed to be steadier in that the changes were slower than the corresponding fluctuations in the hot cathode rectifier. This type of rectifier can not be operated without a ventilating system because the high temperature that is developed is extremely detrimental to the life of the oxide film. The copper-oxide rectifier transmits a-c. line voltage fluctuations through to the arc just as does the other type of rectifier.

Rotating Equipment

(*a*) *The Synchronous Converter.*—The synchronous converter does not lend itself readily to this application because the low voltage required for the non-rotating high-intensity reflecting lamp necessitates a d-c. output at 42–45 volts and an a-c. input to the rectifier at 28 volts. This presents a very serious problem in slip-ring and a-c. brush design in order to keep the cost of the machine within commercial limits. It is necessary also to use a static transformer in order to bring the existing line voltage to the 28-volt value required for the converter. We do not know of any synchronous converters being offered for use with this type of arc.

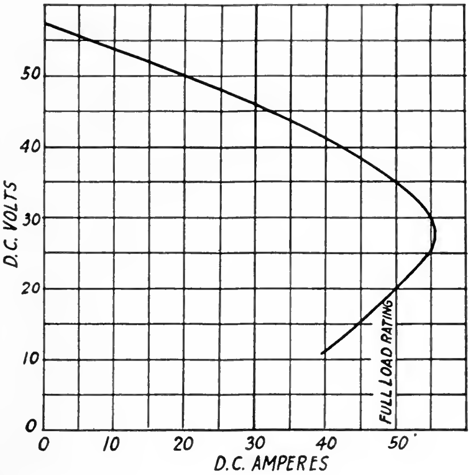

Fig. 3. Fast-drooping characteristic of early shunt-wound generator.

(*b*) *Motor-Generators.*—Motor-generator sets of various types have been used for supplying the direct current to the projection arcs since the advent of the motion picture. In the early days, a shunt-wound generator having a fast-drooping volt-ampere characteristic, such as shown in Fig. 3, was used. This generator was very successful with the old style vertical carbon arc having an arc voltage of approximately 55 volts. The first of these generators was built to operate one lamp only; and when it was desired to make the change-over, the arc for the second lamp was "stolen" from the first, the two arcs being connected in parallel with no ballast resistance in the arc circuits. The instant the arc was struck on the second projector, the arc on the first projector would be extinguished. Such a condition was not satisfactory from an operating standpoint, with the result that later developments raised the possible operating voltage of the generator so that two arcs could be simultaneously operated in series during the period of change-over. The old series arc sets were very efficient inasmuch as they utilized the entire copper capacity of the generator at rated load. The magnetic circuit, however, had to be of such proportions as to carry sufficient magnetic flux to produce the required open-circuit voltage; consequently, the material costs of these machines were a little higher than those of constant-voltage machines for the same operating voltage and normal full-load current. The over-all efficiency from line to generator was high, due to the absence of ballast resistance in the projection arc circuit.

When used with the non-rotating, high-intensity lamp, this type of generator must be designed for a lower operating voltage than was desirable when it was used with the old style open arc. It also has to be designed so that within the operating range of voltage, the current will tend to increase slightly with decreased arc voltage. This is necessary in order to assure any stability of the d-c. arc, and is one of the characteristics of the horizontal arcs wherein they differ from the vertical arcs formerly used.

It has been found with the shunt-wound type of generator using no ballast resistance between the generator and the arc, that unless a reverse series field is used to produce the constant-current effect, making it differentially compound, it is difficult to attain perfect commutation and long life of the commutator. In order to maintain the current approximately constant with this type of machine without a reverse series field, it is necessary to shift the brushes in the direction of rotation so that the armature reactions are demagnetizing. If not carried too far, this would provide a better commutating position than the no-load neutral point on a non-interpole machine; but to gain this result, the brush-shift has to be greater than is desirable to attain good commutation, and the coils undergoing commutation would then be outside the commutating field. Poor commutation results also from insufficient saturation of the magnetic circuit, since the latter is saturated at the open-circuit voltage while at the operating voltage the main pole flux is weak. In one type of motor-generator set that was quite popular several years ago, the commutation was materially improved and made satisfactory by an adjustable interpole, the position of which could be shifted so that its field was directly over the coil undergoing commutation when the brushes were shifted to attain a practically constant current.

Unsatisfactory commutation is not always evident when the generator is first put into operation. A burning apparently occurs beneath the brush, which does not cause visible sparking and does not manifest itself until the machine has been in service for some time, when the commutator begins to blacken and trouble begins.

When the non-rotating, high-intensity reflecting arc was first proposed it was found possible to operate it directly across the terminals of a constant-voltage generator and obtain a steady arc. It was found, however, that additional stability of the arc could be gained by using a small ballast resistance in the arc circuit with a constant-voltage, d-c. source. While the arc operating directly across the generator was perfectly stable under laboratory conditions, it was soon discovered that under operating conditions, and because of the wide variation in ideas as to what constituted proper arc voltage, the operation was not so successful.

The over-all efficiency of the series type of dual generator unit (using two generators driven by a single motor) built for use with the non-rotating, high-intensity arc, averages 60 per cent when delivering 50 amperes at 35 volts. This presupposes that the field circuit of the generator that is not supplying current to the arc is open, and is thus not consuming power needlessly. The power-factor averages 82 per cent on normal load. The inrush of current to the arc when struck is 77 amperes. The commutator ripple is a very complex wave, but is practically negligible, resulting in an extremely quiet arc. As the two generators are driven by a single motor, the first arc will show a diminution in light when the second arc is struck, due to the increased slip of the motor. When operating one arc continuously, the current varies from 48 to 53 amperes, the arc voltage varying from 35 to 38 volts when maintaining a constant arc length.

Where shunt-wound generators having drooping characteristics are used to supply current in the modern theater it is customary to use one generator for each lamp. In some cases the two generators are driven by a single motor. The connections to the lamp switches are made in such a manner in some cases that the field circuit of the generator is not energized while the arc is off; when the lamp switch is closed, the field is energized just before the arc is struck. The output voltage decreases as the temperature of the field windings increases, the decrease being most rapid during the first ten to fifteen minutes of operation. In order to minimize this effect, in occasional installations the field circuits of the two machines are kept closed even when the machine is not delivering current to the arc. The idle machine delivers a high open-circuit voltage, causing excessive copper loss in the shunt field coils as well as a high iron loss, and the generator runs much hotter than normal. Although operating in this manner lessens the change that occurs in the output current and voltage due to the temperature changes of the field windings, it results in a lowering of the over-all efficiency of the set from 60 to 53.7 per cent.

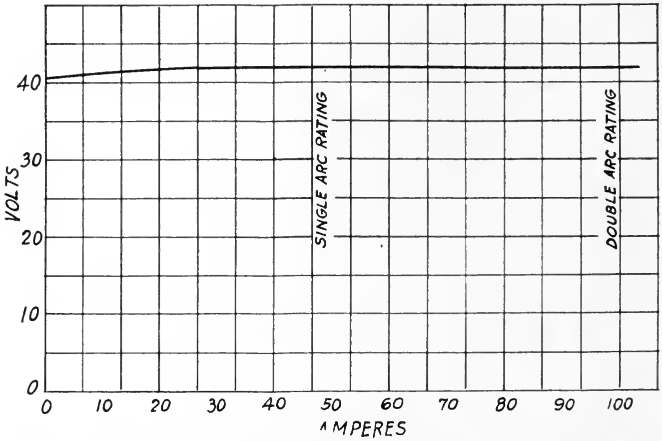

FIG. 4. Volt-ampere characteristic of flat-compounded generator of double-arc capacity.

The flat-compounded generator can be designed for the best operating characteristic both as regards voltage regulation and commutation. The magnetic circuit can be designed so that a fair degree of saturation is attained under normal operating loads. The interpole field can be proportioned so as to neutralize the armature reaction and also provide a commutating field of the proper strength for perfect commutation. The brush position can be regulated so that it is squarely in the commutating field. This type of generator is generally understood by the average electrical maintenance man. Incidentally, it will also carry a heavy overload, should occasion arise, whereas the drooping characteristic unit is limited to practically its rated amount.

After a long series of tests using various generator voltages with corresponding values of series resistance, it was found that a generator having a very flat volt-ampere characteristic at 42 volts, with sufficient ballast resistance to maintain the proper arc voltage of 35 volts, would be very stable in operation (Fig. 4). For the best results from a machine of this type, the design must be such that the commutator ripple is reduced to a minimum, and that the copper loading in the armature, interpole, and series field coils is very low; in other words, the resistance drops must be practically negligible. The over-all efficiency from power line to lamp of a constant-voltage machine of this type when delivering 50 amperes at an arc voltage of 35 volts is 60 per cent, including the rheostat drop. The power-factor in the case of single arc loading with one lamp operating is 83 per cent. The inrush of current to the arc when struck, using the 42-volt generator with a suitable ballast and without auxiliary equipment, is 95 amperes.

In the investigations of commutator ripple, it was found that when an armature was used in which the slots were parallel to the armature shaft, the frequency and magnitude of the ripple were practically independent of the number of commutator bars; that is, an armature with 36 slots, 72 bars, and 72 coils of three turns each gave practically the same amount of commutator ripple as an armature with 36 slots, 108 bars, and 108 coils of two turns each, the frequency of the ripple in both cases being identical. When, however, the armature slots were skewed one slot pitch on the periphery of the armature, the commutator ripple was reduced very materially and arc noise was almost entirely eliminated. In fact, unless the surrounding conditions are such that there was absolute quiet, the noise of the arc could not be heard; whereas quite an audible sound was produced when the arc was supplied with current by a generator having straight armature slots. The ripple voltage in the skew slot armature was about one-eighth of that of the straight slot armature, other conditions being the same. A feature of the low-voltage machine is that, although the arc may be susceptible to variations of voltage and current, the variations are such that the resultant of the several factors remains substantially constant, as is evidenced by the practically constant illumination of the screen.

A-c. line voltage fluctuations have no effect upon the output of the motor-generator set unless the voltage drops to such a value that the motor slip is abnormal. This would mean a reduction in a-c. voltage of probably 35 or 40 per cent before any perceptible change would occur. The speed of the rotating parts being maintained practically constant, resulting in a constant output to the projection lamps, there is no magnetic connection between the input and the output of the motor-generator set.

TRENDS IN 16-MM. PROJECTION, WITH SPECIAL REFERENCE TO SOUND[*]

A. SHAPIRO[**]

***Summary.**—A brief review of the development of 16-mm. sound-film projection and the possible progress in industrial, educational, and non-theatrical uses.*

The purpose of this paper is to review briefly the progress made in the development of 16-mm. projection, the effect upon it of the introduction of sound, and to determine what trends are discernible in this rapidly moving industry.

Originating as a hobby for amateurs, 16-mm. films during the initial period of growth found their largest market in the home field Despite remarkable developments that projected its utility into 35-mm. domains, in the minds of many who have not followed its progress closely, 16-mm. motion pictures are still thought of in terms of imitation rather than as successor to the larger films.

Some five years ago, in an effort to demonstrate the professional possibilities of 16-mm. pictures, the writer displayed a new projector at a convention of the Society held at Washington, D. C. It was pointed out then that the trend of design must give consideration to the professional rather than to the home field. As indication of this trend, a picture was projected with the machine that was displayed that almost filled a theatrical screen 14 feet in width, using only a 250-watt, 20-volt standard incandescent projection lamp, the projector being some 70 feet from the screen.

It is of particular interest to review the progress that has been made since that demonstration. Considering projection only, the most important improvement has been in illumination. Projection lamp design has made remarkable progress. Lamps of 1000-watt capacity are now available for 16-mm. use. Optics and film-moving mechanisms are far more efficient than formerly. Without any substantial increase in size or weight of equipment, the illumination today has

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[*] Presented at the Spring, 1935, Meeting at Hollywood, Calif.

[**] Ampro Corp., Chicago, Ill.

definitely reached the auditorium stage. Five years ago, it was a novelty to project a theatrical-size picture in an auditorium having a capacity of 500 persons. Today it is commonplace, and numerous instances can be found where the 16-mm. projector, formerly referred to as the "little brother of the 35," is being operated in projection booths in place of the larger equipment.

With this advance in illumination, the field of usefulness of 16-mm. projection has rapidly increased. Industry, which had long realized the value of 35-mm. films for sales and business purposes, found the improved 16-mm. equipment much more convenient than the heavier and more cumbersome 35-mm. projectors. In education, where extensive libraries of teaching films had been developed as visual aids, the 16-mm. equipment was quickly accepted as the more desirable in view of its lack of fire hazards, lighter weight, and ease of operation. In non-theatrical fields, such as churches, clubs, lodges, and social groups, the 16-mm. equipment has increasingly become the favored standard for auditorium projection.

With the advent of sound, it looked at first as though the 16-mm. industry had found a real stumbling block. It seemed incredible that satisfactory sound could be photographed and reproduced on the 16-mm. film, which operated at two-fifths the speed of the 35-mm. It seemed impossible that the complicated mechanism of sound reproduction could be added in a compact and light-weight portable form to 16-mm. equipment and at the same time achieve comparable sound effects.

A short period followed in which the industry was frankly perplexed. It tried to effect a compromise by using synchronized disk records on an attached turntable for the sound. This did not prove to be a happy solution, and it was soon realized that 16-mm. sound reproduction would have to march in the footsteps of the 35-mm. with the sound on the film, just as it did in projection.

Early work with 16-mm. sound-film had not been encouraging from the standpoint of sound quality. The limitations of film size and the slower linear speed for light-beam scanning resulted in substantial losses in 16-mm. sound reproduction as compared to 35-mm. Radio had set a definite standard for sound quality, and it was generally conceded that 16-mm. sound would not be satisfactory until it reached, and preferably exceeded, the quality attainable with radio reproducers of the best grade.

Meanwhile the revolution that sound had created in the 35-mm.

field had its reverberations in the 16-mm. field. Insistent demands arose from the industrial, educational, and non-theatrical fields that 16-mm. equipment provide the advantages of sound as well as the picture. Even the home field became to some extent dissatisfied with home movies without sound, and home talkies gave promise of large outlets for the industry.

Happily for 16-mm. movies, progress in sound recording advanced rapidly. With the advent of high-fidelity recording, with its greatly enlarged range of frequencies, in combination with great advances in optical reduction printing, the losses of 16-mm. sound-film became of lesser significance. Continued improvements finally made it possible to provide a quality of sound with 16-mm. film comparable to the best reproduction on high-class radio sets. A frequency range of 50 to 7000 cycles became possible, while output capacities of 15 watts or more, with negligible distortion, proved adequate for auditorium use.

Where is 16-mm. sound-film most extensively used at the present time? It is quite safe to say that industry is by far the largest user. Such representative large corporations as Chrysler Motors, Firestone Tire & Rubber Company, Portland Cement Company, Hormel Company, General Motors Corporation, and hundreds of others too numerous to mention, are utilizing 16-mm. sound for many purposes. It is being used as a sales medium to consumers, as a training medium for dealers and salesmen, and as an educational medium for employee instruction. The production of these industrial 16-mm. sound pictures has become a large industry in itself, and a constantly increasing supply of film for such purposes is being made.

The educational field, which had already recognized the silent picture as one of the most valuable aids to visual education, recognizes in the sound picture a still more effective aid. However, the library of educational sound-films is still relatively small. The educational field is only awaiting the increasing of this library to take on 16-mm. sound in an extensive way. Even with the present small library, hundreds of schools are already equipped with 16-mm. sound projectors in the expectation that sound libraries will quickly and greatly increase.

The addition of sound to 16-mm. film has given the church, the club, and other non-theatrical fields a great stimulus. Circulating libraries of 16-mm. sound-film are now operating in a number of large cities, and rental rates are but slightly higher than for silent films. About 1000 subjects of entertainment character are now available, and this number will undoubtedly increase rapidly. This will, in turn, greatly increase the demand for equipment.

The home talkie field, likewise, is dependent to a considerable extent upon the further development of suitable libraries of rental sound-film. The introduction of a 16-mm. sound camera for amateurs has stimulated a corresponding demand for sound projectors. The higher cost of such equipment, however, has prevented its more general use. With lower costs, based upon designs particularly adapted for home use, this field will no doubt broaden considerably.

We come, now, to a consideration of what lies ahead for 16-mm. sound. We have seen how it quickly outgrew its original limitations, and with its increased light power, advanced into 35-mm. territory for industrial, educational, and non-theatrical purposes. In these fields, it unquestionably has tremendous unexploited possibilities, but, can it not go farther?

What about the theatrical field? Has 16-mm. projection a destiny in the thousands of moderate-size theaters? The answers to these questions seem to depend upon two factors: one, the ability of 16-mm. equipment designers to improve their products further; the other, the attitude of film producers toward furnishing their releases on 16-mm. sound-film, so as to enlarge the available entertainment film library.

The rapid progress made to date in 16-mm. equipment design and illumination gives every promise that the first factor will be attained. Already hundreds of performances are daily being given on 16-mm. equipment to groups up to 1000 persons, showing pictures upon large screens. In most cases, the audience is hardly aware that the equipment used is not 35-mm. The lamp manufacturers have for some time given serious consideration to improving the illumination further, and experimenting with such lamps will undoubtedly result in a tremendous gain in 16-mm. illumination. Likewise, sound improvement has already enabled 16-mm. equipment to fill the requirements of moderate-size theaters.

With regard to the second factor, the producers have so far been apathetic to releasing prints on 16-mm. sound-film. This has not only retarded the 16-mm. growth in the theatrical field, but has hampered the growth in the non-theatrical and other fields requiring entertainment film. Whatever the reasons for this attitude may be, it is certainly not justified upon the basis of a comparison of operating factors between 35- and 16-mm. films.

For example, compare the factor of safety between the two films. While 35-mm. film of a non-inflammable type can be obtained, by far the greater amount used is extremely inflammable. Many cities recognize the fire hazard this provokes, and require fire-proofed booths for 35-mm. projection. All 16-mm. film is non-inflammable or slow burning. Its safety has been recognized, so that no restrictions prevent its use, even in the open. As an instance of this great advantage, it is cited that in many schools children operate the 16-mm. equipment. This can hardly be said of 35-mm. film, which has a definite fire hazard.

Again, the 16-mm. equipment requires no special prolonged training for competent operation. Again citing the experience in schools, it is found that such equipment is generally operated by the teachers or by their pupils. Its small size and weight enable it to be easily transported, thus encouraging its use in many places. This is a definite increase in its utility for road shows and circuit entertainments. Its simplicity results in substantial operating economies.

Another factor that offers an interesting comparison is the cost of distribution. A 1600-ft. reel of 16-mm. film weighs 5 pounds, and such a reel can deliver an uninterrupted program lasting 44 minutes. A 1000-ft. reel of 35-mm. film weighs about 6 pounds and can deliver a program lasting only 11 minutes. In other words, the weight of a similar program is more than four times as great on 35-mm. film as on 16-mm. film. What a tremendous saving in shipping alone, besides the savings in container, packaging, handling, *etc.*

Finally, there is the economy of equipment. Not only is 16-mm. sound equipment far less expensive than 35-mm.; but, in addition, the theater can very often get along with one 16-mm. projector, whereas it would require two 35-mm. equipments. Since the 1600-ft. reel of 16-mm. film can deliver a program equal to that of four 35-mm. reels, the projector need be re-threaded only once during an eight-reel program. This is not objectionable in the smaller houses, which, with 35-mm. film, would require two projectors; otherwise, there would be seven interruptions in an eight-reel program.

These considerations of lower costs are of vital importance to large numbers of the smaller theaters located in outlying sections. Their operating expenses have become disproportionate to their reduced incomes, forcing a number to close. In spite of considerable improvement in the theater business, some 3000 small houses are still closed. In many cases, the lower cost of 16-mm. sound-film would enable such theaters to reopen upon a profitable basis. This, in turn, would increase the revenue of the film producers, who are now limited as to the number of theaters that can profitably take their releases.

To summarize, it would appear that the immediate expansion of the 16-mm. sound market lies in industry, education, and non-theatrical fields. Film sources to supply these fields are growing rapidly. Industrial film producers are increasing their 16-mm. sound productions, several universities are producing 16-mm. sound educational pictures, and entertainment libraries are growing to supply the non-theatrical and home fields.

The future trend, with regard to the smaller theaters, is problematical. It will require producer coöperation as well as improved equipment design. With such coöperation, the smaller theaters with capacities of approximately 600 persons and screens about 18 feet in width, which represent about 70 per cent of the total theaters in this country, can operate upon a more profitable basis than by using 35-mm. sound-film.

All indications point, however, to the trend of 16-mm. sound toward professional pursuits. It has outgrown the home field as a major outlet. It is destined more and more to be used as a tool for industry, as an effective aid for education, and as a flexible medium for cultural and recreational activities.

SYMPOSIUM ON NEW MOTION PICTURE APPARATUS

A WIDE-RANGE STUDIO SPOT LAMP FOR USE WITH 2000-WATT FILAMENT GLOBES*

E. C. RICHARDSON**

During the Spring Convention at Hollywood, Calif., May 20–24, 1935, a symposium on new motion picture apparatus was held, in which various manufacturers of equipment described and demonstrated their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

In the motion picture studios there are a number of lamps that may be classified under the general term of "spot lamp." For the purpose of this paper, this classification may be divided into two groups, *i. e.*, the condenser type and the reflector type. The condenser type embodies a source of illumination, the light from which is collected by means of a single condensing lens, usually of the plano-convex form, and means are provided for focusing the light-source in relation to the lens in order to vary the divergence of the projected beam. The ratings of these lamps range from 250 to 2000 watts, utilizing filament globes; and, in carbon arc equipment, from 35 to 115 amperes.

In the group of lamps designated as the reflector type will be found the lamps embodying light-sources in combination with glass or metal reflectors, usually of the paraboloid form. It is the present practice of the motion picture studios to use lamps of the reflector type provided with incandescent globes, with reflectors ranging in diameter from 18 to 36 inches. Carbon arc equipment of the reflector type includes the Sun arcs, the majority of which have reflectors 24 or 36 inches in diameter, although one major studio employs several Sun arcs using 60-inch reflectors.

The characteristic common to both the previously mentioned groups is that they may be used to project a beam of light, the divergence of which may be varied from a narrow angle, for the "spot," to an angle sufficiently wide to "flood" a considerable area. By altering the angle of divergence of the projected light-beam, the area covered by the beam and the intensity within the beam may be increased or decreased according to requirements.

In attempting to improve any product three considerations come to one's attention: first, the incapacity of the existing product to meet the demands im-

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Mole-Richardson, Inc., Hollywood, Calif.

posed upon it; second, the extension of the usefulness of the product into new fields of use; and, third, increasing the efficiency of the product itself.

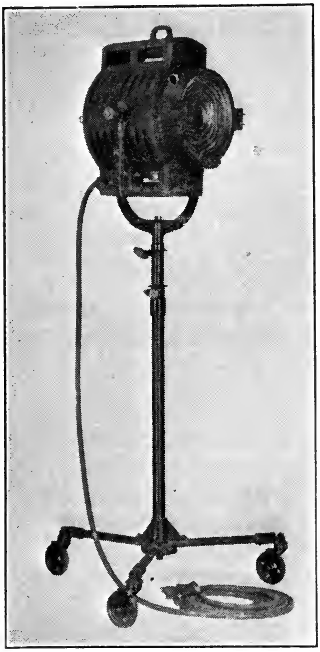

FIG. 1. *MR* Type *210*, Junior Solarspot.

The lamp under consideration in this paper—the *MR* Type *210* Junior Solarspot, shown in Fig. 1—has been designed to function primarily as a spot lamp for use in photographing motion pictures. It is not an adaptation of equipment used in another field of illumination, but embodies in its design characteristics for overcoming the inability of existing equipment to fulfill the demands imposed upon it and provides a control of the light-beam that widens the utility of the lamp as a tool of the cinematographer. The advantages achieved in this design have been largely effected by more efficiently utilizing the light from the 2000-watt *G48 C13* bipost type of filament globe used in this equipment as the light-source.

Spot lamps of the condenser type have the advantage of good control over the projected beam. Using a 2000-watt lamp as the source, the beam can be converged to an angle of 8 degrees and flooded out to an angle as great as 45 degrees, although at such wide divergence the intensity of illumination is low. The disadvantage of spot lamps using the tungsten filament globes is their inefficient utilization of the light.

The power radiated by the 2000-watt globe is nearly 3 hp., a considerable portion of which is radiated at wavelengths lying below the visible range. That is to say, in other words, that the 2000-watt lamp radiates a lot of heat. The amount of heat radiated is such that even

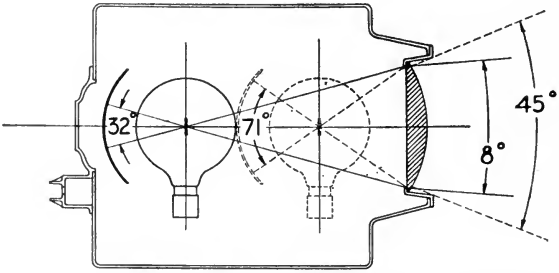

FIG. 2. Construction of typical 2000-watt condenser type studio spot.

though plano-convex lenses are made of heat-resisting glass, their size in practical application, and to prevent excessive breakage, seems to be limited to a diameter of 8 inches and a focal length of 15 inches.

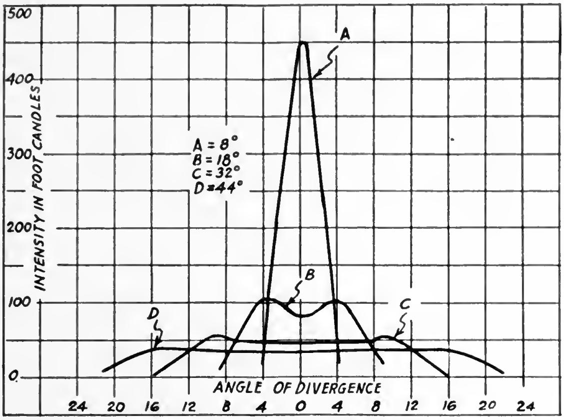

FIG. 3. Intensity distribution of condenser type spot lamp, with 8-inch diameter, 15-inch focus condenser; source: 120-volt, 2000-watt, *G-48* bipost incandescent lamp.

Fig. 2 illustrates the layout of a typical 2000-watt condenser type studio spot. Behind the globe is a spherical mirror which is used to collect the light that would otherwise be unprojected and to reflect it so as to form an image between the coils of the filament grid. Tests reveal that when such a mirror is used in the combination shown in Fig. 2, good adjustment will increase the intensity of the beam by approximately 60–75 per cent above that afforded by a globe without such a reflector. With a beam divergence of 8 degrees in the spot lamp illustrated, it is possible to effect such a collection of direct and reflected light upon the condenser lens of only 32 degrees. When such a combination is used for flooding, with a beam divergence of 45 degrees, the angle of the collected light is increased to 71 degrees, but the intensity of the beam is so low that it is not of great photographic use. Fig. 3 shows the angular distribution of candle-power from a 2000-watt studio spot for beam divergences of 8, 18, 30, and 44 degrees.

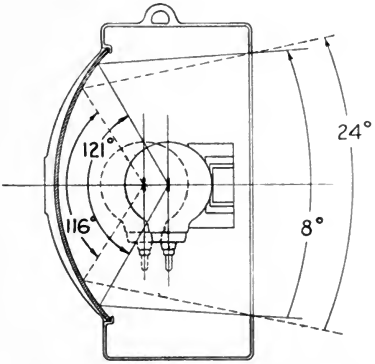

FIG. 4. Reflector type of lamp equipped with parabolic mirror, showing angles of collection for spot and flood positions.

The inherent fault of the condenser type of spot lamp for use with high-wattage globes is its incapacity to collect a large proportion of the light emitted by the source. Short-focus, wide-aperture condenser lenses would correct the difficulty; but for the plano-convex type of condenser, lenses of suitable focal length would be so thick as to cause great losses in transmission, and the breakage hazard, which is now rather objectionable, would be greatly increased due to the thickness of the lenses.

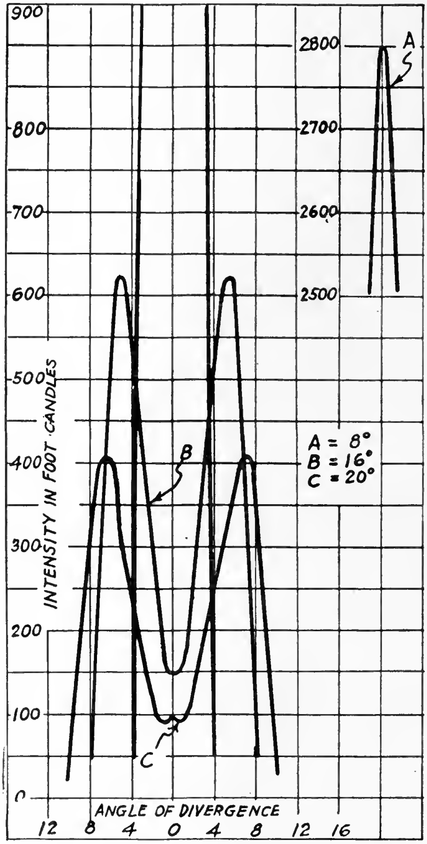

FIG. 5. Intensity distribution of reflector type of spot lamp, with 18-inch parabolic reflector and spill ring; source: 120-volt, 2000-watt, *G48* bipost incandescent lamp.

The reflector types of lamp have the advantage over the previously described condenser spot lamps of collecting from the source a larger angle of light. A schematic drawing of a lamp equipped with a parabolic mirror 18 inches in diameter and having a focal length of 7$^7/_8$ inches is shown in Fig. 4. The layout shows the lamp adjusted for a narrower beam of 8 degrees, in which case light within an angle of 121 degrees is collected from the bulb. The dotted lines show the position when the light is flooded to an angle of 24 degrees, in which case the angle of collection of the mirror is 116 degrees. All the light from the front of the globe is lost, since, with the super-speed film in present use, it is necessary to apply spill rings to prevent any unprojected light from falling upon the set that may cause overexposure. This optical combination is most effective for narrow beam divergences in the lamps using 2000-watt, *G48 C13* globes as the source.

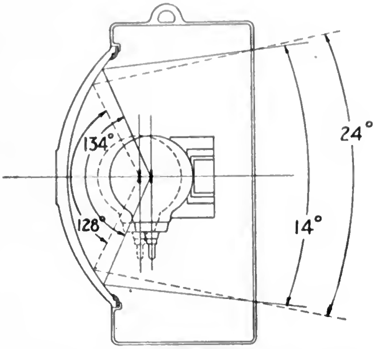

FIG. 6. Showing angles of collection of light in the 18-inch Sunspot lamp equipped with mirror.

Lamps of this type will spot down to a divergence of 8 degrees without projecting filament images that are seriously objectionable. When such narrow di-

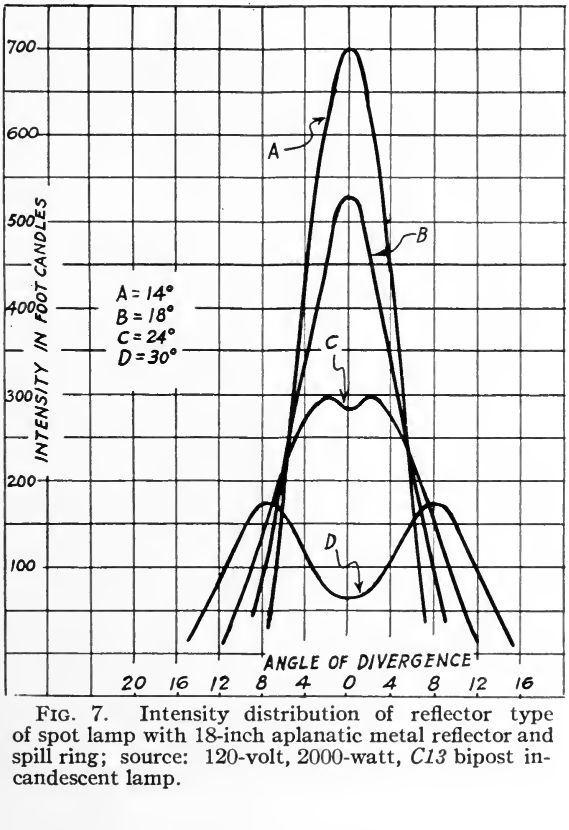

FIG. 7. Intensity distribution of reflector type of spot lamp with 18-inch aplanatic metal reflector and spill ring; source: 120-volt, 2000-watt, *C13* bipost incandescent lamp.

vergences are required, lamps of this type are most effective; but the effectiveness is lost when they are flooded due to the characteristics of the parabolic reflectors. When the source is placed inside the focus of the reflector the intensity at and near the center of the beam drops much more rapidly than at the edges of the beam. This condition begins as soon as the globe is moved in from the focal point, and becomes more and more pronounced as the divergence increases; until, when the divergence is great enough, the projected light forms a "doughnut," which has no illuminating value in motion picture photography. Diffusing mediums can correct the bad distribution somewhat, but at the expense of much loss of illumination. Fig. 5 shows the intensity distribution of this type of equipment for divergences of 8, 16, and 20 degrees.

To overcome this fault of the parabolic mirror when used for projecting other than narrow beams, there are in use in the motion picture industry stamped metal mirrors, the curvature of which is primarily parabolic, but having a plurality of facets. This type of mirror design injects an element of diffusion which improves the distribution of intensity in the projected beam. Fig. 6 shows an 18-inch Sun spot in which such a mirror is installed, and the angle of collection of the light. For the 14-degree divergence the angle of collection is 130 degrees, and for the 24-degree flood position it is 124 degrees. While mirrors of this design may be constructed from a number of small pieces of glass, a form of reflector frequently used in Europe, such construction is not, in our opinion, satisfactory. The amount of handwork involved in producing such a reflector in our country would make its cost prohibitive. Such reflectors have always tended to deteriorate rapidly, the silver peeling at the edges of the facets. The faceted metal mirrors used in the Hollywood studios are finished to a high degree, and are chromium plated. Their reflectivity is, of course, limited by the reflectivity of the chromium-plated surface. Their particular virtue is the smoothness of distribu-

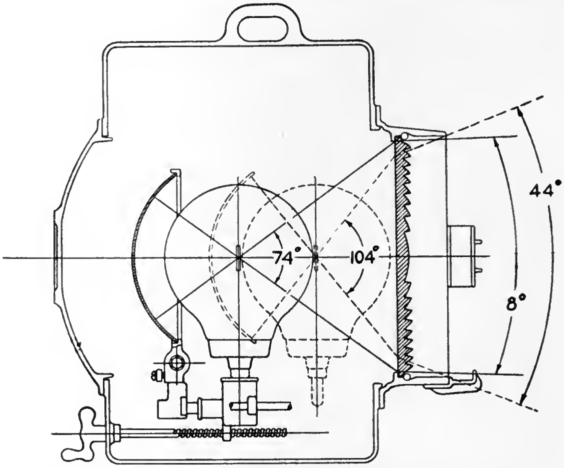

FIG. 8. *MR 210* Junior Solarspot lamp, equipped with concentric plano-convex Fresnel lens.

tion, for divergences from 14 to 24 degrees. The angular distribution of an 18-inch Sun spot employing a faceted metal mirror and a 2000-watt *G48 C13* Mazda globe is shown in Fig. 7 for angles of 14 (the narrowest divergence), 18, 24, and 30 degrees.

In the motion picture industry it is seldom necessary to project a spot beam narrower than 10 degrees, which provides a spot of light about eight feet in diameter at a distance of fifty feet. It is, however, desirable to be able to flood a lamp to a divergence as great as 40 degrees, provided that the projected beam at this wide angle is of sufficient intensity to be of photographic use. For the conditions under which spot lamps are used, it is desirable that the beam have its highest intensity at the center and that the edges be soft so as to permit overlapping the beams of several such lamps without building up high intensities in the areas overlapped.

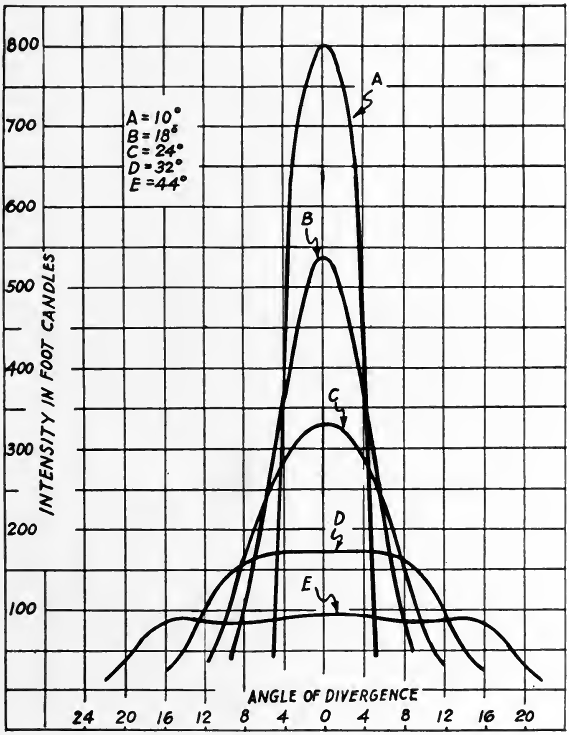

FIG. 9. Intensity distribution of Junior Solarspot; source: 120-volt, 2000-watt, *G48 C13* bipost incandescent lamp.

The *MR* Type *210* Junior Solarspot lamp, illustrated in Fig. 8, is supplied with a lens of the type known as the concentric plano-convex Fresnel. A lens of this type can be made quite large in diameter, of short focal length, and of relatively thin section. This lens was designed particularly to fulfill the requirements of the Junior Solarspot; and when used in combination with a 2000-watt *G48 C13* Mazda globe will project a spot beam having a divergence of 8 degrees, and a flood beam of 44 degrees. The lens is manufactured of a superior, heat-resisting glass of high mechanical strength. Referring to Fig. 8, at the rear of the globe is provided a spherical mirror of the proper radius and aperture diameter, provided with two simple adjustments. This lamp utilizes a 2000-watt *G48 C13* bipost Mazda globe. Such globes are, by their nature, virtually prefocusing; and when once the adjustments in the lamp are set, globes may be mounted or dismounted, and only slight readjustments of the spherical mirror are required to attain high efficiency of projection. The wide-aperture, short-focus lenses permit combined collection of the radiation from the globe and the spherical mirror within an angle of 74 degrees in the position for an 8-degree divergence, and of 104 degrees when the lamp is used in its maximum flood position for a divergence of 44 degrees. The short-focus Fresnel lens contributes to the over-all efficiency of the unit, but only careful attention to the design of the lens has made possible the excellent distribution provided by the equipment over a wide range of beam divergence.

Fig. 9 shows the angular distribution of the Junior Solarspot for beam divergences of 8, 18, 24, 30, and 40 degrees. It will be noted that the wide range of distribution and the degree of intensity attained by this new equipment adapts it to a wide range of use in motion picture photography. For instance, with this lamp a person may be covered from head to foot at a distance of ten feet. A spot that can be flooded to this degree and to such an intensity makes a very useful lamp for general lighting. The fact that the projected spot at all times has soft diffusing edges permitting areas to be overlapped without showing rings or bands of lights, especially adapts it to back-lighting; and the wide range of intensity within the various beams is particularly advantageous for such purposes.

Much experimentation has been done with an iris shutter applied to the lamp. By closing the iris and adjusting the focus of the lamp, a wide range of intensity may be attained for a given beam divergence for any type of photography demanding that the spectral composition be maintained constant, as for color photography. Control of intensity by an iris is most desirable, in avoiding the use of diffusing screens which have the characteristic of absorbing certain wavelengths and otherwise causing spectral imbalance.

AN AUTOMATIC DAYLIGHT CONTINUOUS 35-MM. PROJECTION MACHINE*

A. B. SCOTT**

The S. C. K. projector (Fig. 10) is intended for continuous projection from a large loop of film during long periods of time. The machine is equipped with a single magazine into which is built the non-rewind device. Pictures may be pro-

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** S. C. K. Corporation, Hollywood, Calif.

jected upon a reflecting screen in the usual way or upon a translucent sand blown glass screen. For the latter type of projection the various elements in the sound reproduction system can be rearranged in thirty-five seconds. The machine is provided with an automatic cut-off, which, in case the film breaks, stops all moving parts as well as the light and the sound, before the film travels eight frames.

The average film is worn badly when it has been shown a maximum of 125 times under ordinary projection conditions, due to three principal factors, namely scratches resulting from the imperceptible slippage and friction of the film, excessive heating, and finally, wear on the perforations. In this machine, slippage and friction are minimized. When the machine is going at the full speed of 90 feet per minute, it is possible to put a finger between any two layers of the film. Heating is lessened by a special fan which draws the heat out of the projection chamber and blows a cooling draft of air upon the film after it passes through the projection chamber and before it is rewound. Wear and tear of the perforations at the intermittent movement are completely eliminated, as no sprocket of any kind is used. These three unique patented features make it possible to keep ordinary film in excellent condition for a minimum of three thousand showings.

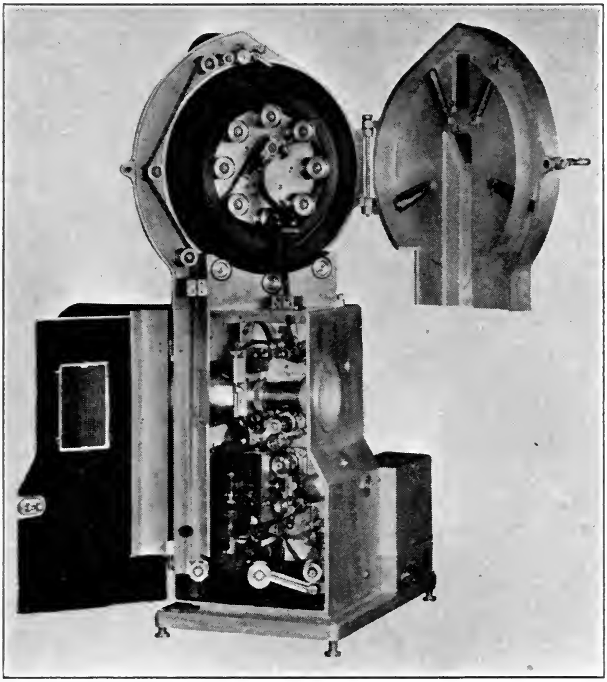

FIG. 10. S. C. K. automatic daylight continuous, 35-mm. projector.

This machine is manufactured with a single picture projecting head or with a triple head. This triple-head automatic machine can be used on the marquee of a theater for projecting trailers on three screens simultaneously, so that they are visible from any direction. If there is any excuse for trailers it is to have them on the outside of the theater to induce people to enter, and not to bore them after they have paid their admission.

By another very simple device attached to the three-head machine, two trailers can be run, with an automatic sign telling the public which picture is being shown at the present time and which is the coming attraction.

THE VITACHROME DIFFUSIONLITE SYSTEM AND ITS APPLICATION*

A. C. JENKING**

The "Diffusionlite system," the term applied to this form of illumination, was discovered more or less accidentally after repeated efforts to get away from the use of expensive condensers or diffusers during a long period of years of constructing large projecting and enlarging cameras. It was found that by using a mirror at the front of the lamp and projecting all the light upon an electrolytically treated aluminum surface the result was excellent. The light reflected from the myriads of microscopic brilliant facets formed a beam of illumination that was uniform, well distributed, and without perceptible "spot" or "center" or figuration, yet remarkable in its brilliancy and penetration. The resulting enlargements were more beautiful than any we had produced before. This led us to seek a means of employing the same principle for studio lighting. An object could then be photographed with a perfectly diffused light without having to interpose glass or silk screens and thus lose considerable brilliancy.

Fig. 11 shows the 500-watt *PS-40* lamp, which, at the proper voltage, has a life of 1000 hours. Upon the bulb is deposited, by evaporation, a metallic reflecting surface of high efficiency. The mirror-coated area is calculated to have just the right diameter and curvature and, owing to the thinness of the glass, is to all purposes a front-surface mirror, throwing directly upon the reflector uniform illumination without "hot-spot," rings or images of the filament. The tests of these mirrors show a reflection coefficient greater than 80 per cent.

It was only after many experiments and tests that the process was brought to a point where the mirrors could be guaranteed to stay upon the bulbs and retain their full reflection characteristics for the entire life of the lamps. These requirements have been met even in the case of the 2-kw. lamps used in the spots. The brick-colored coating upon the outside surface is a refractory material, placed there to protect the mirror which is so thin that it can be measured only by optical means.

The lamp bulb is hung in the housing so that no direct rays escape. The mirror reflects back all the forward rays, and thus all rays emitted from the filament

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*Presented at the Spring, 1935, Meeting at Hollywood, Calif.

**Vitachrome, Inc., Los Angeles, Calif.

are diffused by reflection from the countless facets of the electrolytically treated bowl. The curvature of the diffusion bowl has been carefully calculated to gain a high degree of efficiency and to avoid entrapping any light. Tests have shown that excellent diffusion is attained with a loss of only 5 or 6 per cent of light. There is a definite improvement in the brilliancy, without glare or "burning" the picture. The 500-watt model has the greatest general use in all fields of photography as well as motion pictures, in which this size is not used for close-ups or key lighting. The 2000-watt lamp is designed for general lighting of larger sets. Both lamps are otherwise patterned alike, and have been especially designed and built from the base up for their purpose.

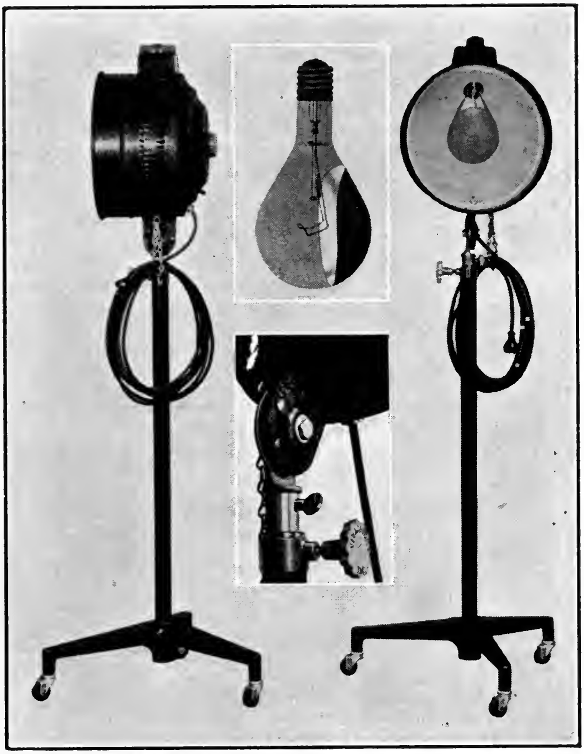

Fig. 11. 500-watt, *PS-40* lamp with metallic reflecting surface deposited upon bulb; collapsible telescopic stand and angle adjustment.

The 500-watt model, while very sturdily built, is extremely light, weighing only 22 pounds. It can be disassembled very quickly by removing the telescopic stem from the castered tripod base. A half dozen of such lamps can then easily be stowed in the rear of a Ford coupe. A frictionally held joint is incorporated between the bottom of the hood and top of the supporting stem, permitting bend-ing the lamp backward or forward into any position, without having to adjust set-screws, *etc.* A ten-step rheostat is constructed within the hood of each lamp. This dimmer eliminates the necessity of screens for reducing the light-intensity. It is durably built and will last indefinitely, working quietly and smoothly.

In order to demonstrate the various properties of the lamp, it may be projected upon a screen. If an object is placed immediately in front of the lamp, no perceptible shadow is cast; and as the object is moved toward the screen, a very indefinite shadow begins to form without at any time becoming a hard shadow unless the object is right up against the screen.

The lamp provides admirable modeling light, with good diffusion and softness, coupled with a penetrating, sparkling brilliancy that may be appreciated by looking directly into it. The light is easy on the eyes, because there is no direct ray.

SOCIETY ANNOUNCEMENTS

ATLANTIC COAST SECTION

The regular monthly meeting of the Section, held on November 13th, at Public School No. 11, New York, N. Y., was well attended, and indicated the extent to which interest in motion pictures for educational purposes is being shown in the New York area. Miss R. Hochheimer acted as Chairlady of the evening, introducing as speakers Dr. J. M. Sheehan, Assistant Superintendent of New York Schools, Mrs. J. H. Kohan, Vice-President of the United Parents Association, and Dr. Albert Brand, of Cornell University. A number of pictures were projected illustrating the nature of the subjects used and the technic followed in visual instruction in the classroom.

As the result of the recent elections, the officers of the Section for the year 1936 will be as follows:

L. W. DAVEE, *Chairman*
D. E. HYNDMAN, *Sec.-Treas.*
M. C. BATSEL, *Manager*
H. GRIFFIN, *Manager*

MID-WEST SECTION

At a meeting held on November 21st at the Electrical Association, Chicago, Ill., Mr. H. A. DeVry presented a paper on the subject of "Science Involved in a Film Reel." The meeting was well attended, and after the discussion of Mr. DeVry's paper, the results of the election of officers of the Section for 1936 were announced as follows:

C. H. STONE, *Chairman*
S. A. LUKES, *Sec.-Treas.*
O. B. DEPUE, *Manager*
B. E. STECHBART, *Manager*

PACIFIC COAST SECTION

At a meeting held on October 4th at the Pathé Studio, Hollywood, a presentation on the subject of lighting equipment was given by Mr. P. Mole, followed by an additional paper on the same subject, but with special reference to the performance of incandescent lamps and their applications, by Mr. R. G. Linderman. Mr. E. Huse spoke on the subject of "Practical Applications of the New Pola Screens in Cinematography." Several reels of films shot with the Pola Screens by cameramen of Hollywood were projected, illustrating very effectively the action of the screens.

STANDARDS COMMITTEE

At a meeting held at the Hotel Pennsylvania, New York, N. Y., on December 4th, extensive consideration was given to the subject of revising the Standards Booklet on the basis of suggestions and criticisms made during the past six months or so and particularly in connection with Mr. G. Friedl's visit to Europe in the interest of 16-mm. sound-film standardization.

In addition, in view of the confusion that might result from the fact that there will exist in commercial use two nominal lengths of film, namely, 1000 and 2000 feet, the application of the word *reel* should be restricted only to the metal appliance upon which the film is wound. In other words, a *reel* of film should no longer be defined as "approximately 1000 feet of film," and the Committee formally took action to delete that definition from the Glossary of the Society.

Voting ballots are being mailed to the Members of the Committee for their action upon this, as well as upon the question of formally adopting the 2000-ft. length of film as an additional standard.

SOCIETY SUPPLIES

Reprints of *Standards of the SMPE and Recommended Practice* may be obtained from the General Office of the Society at the price of twenty-five cents each.

Copies of *Aims and Accomplishments*, an index of the *Transactions* from October, 1916, to June, 1930, containing summaries of all the articles, and author and classified indexes, may be obtained from the General Office at the price of one dollar each. Only a limited number of copies remains.

Certificates of Membership may be obtained from the General Office by all members for the price of one dollar. Lapel buttons of the Society's insignia are also available at the same price.

Black fabrikoid binders, lettered in gold, designed to hold a year's supply of the JOURNAL, may be obtained from the General Office for two dollars each. The purchaser's name and the volume number may be lettered in gold upon the backbone of the binder at an additional charge of fifty cents each.

Requests for any of these supplies should be directed to the General Office of the Society at the Hotel Pennsylvania, New York, N. Y., accompanied by the appropriate remittance.

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CONTENTS

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A NEW METHOD OF INCREASING THE VOLUME RANGE OF TALKING MOTION PICTURES*

N. LEVINSON**

***Summary.**—Lack of adequate volume range is one of the greatest handicaps to achieving greater realism in sound motion pictures. A method of intercutting variable-density and variable-width recordings is described which results in an 8-db. increase in effective volume range.*

One of the chief handicaps toward achieving greater realism in talking motion pictures is the lack of an adequate volume range to reproduce faithfully the wide variations that occur in dialog and music.

The volume difference between the surface noise of the average film record and the maximum signal that can be reproduced from such a record is about 40 decibels. This range is inadequate for recording the gradations of volume required for dialog and is entirely inadequate for the proper dramatic presentation of music.

Due to this limitation of range it is necessary to record upon film at a normal dialog level only 8 or 10 decibels below 100 per cent modulation of the recording device. This allows an increase of only 10 decibels in volume for scenes in which shouting takes place, and also for the opening and closing title music of a picture or a high-volume singing sequence. If the recording level is dropped in order to gain a greater range for these sounds, then the film surface noise becomes objectionable in the normal dialog recordings.

To illustrate the point, assume a volume range of 40 decibels for a good film recording using 10-db. noise reduction. If the modulation level for normal dialog is 10 decibels below 100 per cent modulation, the film surface noise in the theater will be only 30 decibels below the dialog level. The surface noise from films recorded in this manner is usually not objectionable in the average theater, as it is just masked by the audience and the theater noise. If, however, the normal modulation is reduced to a level, say, 15 decibels below 100 per cent

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** Warner Bros.-First National Studios, Burbank, Calif.

modulation, then the gain of the theater amplifier must be increased 5 decibels for the same effective acoustic level of the dialog. The acoustic level of the surface noise is likewise increased 5 decibels so that it is only 25 decibels below the normal speech level. It is no longer masked by theater and audience noise, and becomes very objectionable in the average theater.

Thus the elimination of surface noise in normal speech recordings requires that the speech be recorded at such a high percentage of modulation that no leeway in volume range remains for recording speech and music that require additional range for the best dramatic effect.

One method of increasing the apparent volume range of variable-density recordings is the so-called "squeeze track." In this method of recording, the normal dialog track is, for example, only one-half the maximum width allowable on the release print. Loud musical sequences are released on the full width of the sound-track, with a resultant increase in level of 6 decibels. This method is very effective but, unfortunately, when the track is reduced to one-half the width, the level of the signal is reduced by 6 decibels but the film surface noise is reduced by only 3 decibels. This is due to the random nature of the film background noises which, therefore, must be added vectorially, with a resultant change proportional to the square-root of the change in width of the track. Thus we gain in this method of recording an effective increase in volume range of 3 decibels, assuming that the surface noise for the normal dialog, or during periods of no sound, is held at a constant level. Greater increases in volume range are possible but this example illustrates the current commercial practice.

Another method in general use of increasing the volume range of film recordings is that of increasing the transmission of variable-density sound-track during periods when high volumes are required. It is general practice, at present, to maintain an unmodulated visual diffuse print transmission for variable-density recordings of approximately 20 per cent, this value of print transmission resulting in minimum distortion and most pleasant reproduction of the recorded sound. As is well known, the output level of a variable-density record varies with the print transmission; so if it is desired to reduce the output level, the print may be darkened, or if it is desired to increase the output level, the print may be lightened. Such a change in print transmission is accompanied by a change of quality that is quite small, within the limits of, say, 16 to 30 per cent transmission. When the print transmission is changed beyond these points, however, the quality begins to suffer.

The method described above is widely used to increase the effective volume range of film recordings. Opening title music may be printed for a visual print transmission of, say, 40 per cent, with the result that when reproduced in the theater it is 7.8 decibels louder than the normal dialog. Since the surface noise is objectionable only during periods of low modulation or no modulation, this procedure of increasing the print transmission increases the effective volume range of film recordings by approximately 6 decibels. Any impairment of sound quality that may result in order to attain the loudness required is more than compensated by the increased effectiveness and dramatic value of the sound.

The method to be described in this paper not only achieves this increase in volume range, but it does so without the slightest impairment in quality. It is accomplished by intercutting variable-density recordings with variable-width recordings; variable-density recordings being used when normal volume is required, and variable-width when high volumes are required.

The unmodulated portion of a variable-width recording consists of a sound-track, one half of which is opaque and the other half transparent. Its normal unmodulated transmission, therefore, is approximately 50 per cent, or $2^1/_2$ times the optimal unmodulated transmission for variable-density track. This difference in unmodulated transmission results in producing a variable-width track of the same percentage of modulation at a level approximately 8 decibels higher than that of the variable-density track when run on the same reproducing system with the same gain. Thus, by intercutting variable-density and variable-width recordings, an extension of the range of 8 decibels is provided, without changing the fader setting, for the most effective and dramatic reproduction of sound.

This idea has been found to be very practicable, and of great value in dramatic and musical sequences. It has been further enhanced by intercutting "squeeze track" and variable-width track, with a resultant 11-db. increase in maximum volume for the same noise level in the theater.

The release of such prints has demonstrated that many theaters are equipped with power amplifiers of inadequate capacity for handling the increased volume range. Before the full possibilities of the system can be realized, additional amplifier capacity must be provided in these theaters or more efficient loud speakers must be developed. In spite of the inadequacy of theater equipment, the system has shown itself to have great possibilities for enhancing the realism and naturalness of sound pictures.

APPENDIX

The ratio between the output of a variable-density sound-track of 20 per cent visual diffuse transmission and a variable-width track of the same percentage of modulation, when reproduced with the same gain, is derived as follows:

Variable-Width Recording

Standard width of track	0.070 inch
Diffuse density of opaque portion	1.3
Projection density of opaque portion	1.3 × 1.3 = 1.69
Projected transmission density of opaque portion	2.04 per cent
Diffuse density of transparent portion	0.06
Projection density of transparent portion	0.078
Projected transmission density of transparent portion	83.4 per cent
Percentage change in projected transmission for 50 per cent modulation: (83.4–2.04) × 0.50	40.68
40.68 × 0.070 × K (= Intensity of illumination × height of slit)	2.85K modulated light flux output

Variable-Density Recording

Standard theater reproducing aperture	0.084 inch
Mean diffuse density of print (20 per cent transmission)	0.70
Mean projection density of print (20 per cent transmission)	0.91
Mean projection transmission density of print (20 per cent transmission)	12.3 per cent

Variable-Density Recording

(For 50 Per Cent Modulation)

Maximum projected transmission of print	18.45 per cent
Minimum projected transmission of print	6.15 per cent
Percentage change in projected transmission for 50 per cent	12.3 per cent
modulation: (18.45–6.16) × 0.084 × K	1.032K
$\frac{2.85\ K\ \text{(variable-width track output)}}{1.032\ K\ \text{(variable-density track output)}}$	2.76
20 log 2.76 = ratio of loudness of variable-width track to variable-density track of the same percentage of modulation	8.8 decibels

DISCUSSION

MR. FRANK: One of the producers is releasing, or has in the past released, pictures in two different types of release print, a Class *A* print and a Class *B* print, one of which had an increased volume range. Do other producers, or does the industry as a whole, intend to release regular pictures in two different kinds of print, one the standard release print to be used on equipment such as we now find in the theaters in general, and the other only where adequate reserve power is available?

CHAIRMAN FRAYNE: I believe the studio to which you refer is Metro-Goldwyn-Mayer, and that was in connection with the musical, *Naughty Marietta*. The studio, at the time, attempted to turn out two different prints, on a trial basis, but the experiment was not quite successful because of confusion at the exchanges, and because of the objections of some houses to receiving Class *B* prints. I have not heard of any other studio contemplating such a device at the present time, at least so far as getting different volume outputs from film is concerned.

MR. FRANK: Is it the intent, then, of Warner Bros., for instance, to release pictures, particularly those with musical selections, under the new system, without regard for the theater that does not have adequate reserve power?

PRESIDENT TASKER: I do not know whether I can speak for the West Coast studio, but I should imply from this paper and from conversations with Major Levinson that it was intended to make use of the increased volume range, whether or not the theater was capable of taking advantage of it.

CHAIRMAN FRAYNE: The question as to what volume range we actually get from variable-density track is very much undecided. It depends a good deal upon who makes the measurement, and I believe in order to facilitate matters we ought to have a definition of what we mean by signal-to-noise, or volume range, of a film. If we define volume range as the difference in output between a fully modulated 1000-cycle signal and the noise level of the unmodulated track, then actual measurements indicate that a volume range of approximately 40 decibels without any noise reduction can be obtained from average film processing. If we refer to the average mixing level, assumed to be, say, 10 decibels below clash, then, of course, that figure drops to 30 decibels. But since recording practices vary a great deal, it would seem that the former definition of volume range should be given more weight. As to the 8-db. increase in output of the variable-width over the variable-density track, this is theoretically correct, based upon the average transmission of variable-width track and the average transmission of variable-density track.

MR. EVANS: The question of volume range and noise level has come up before the Sound Committee, and attempts have been made, without much result, to define what was meant by volume range. There are two or three concepts that apparently should be noted. One assumes that the noise level is measured on a flat system, giving one result. Another is that the noise level is measured on a system whose characteristic is that of the ear, giving an entirely different result. Still another, termed *effective* volume range—and it seemed to some members of the Committee that that concept should be defined—concerned the ratio of the loudest to the lowest sounds that it was good practice to record. Volume range should be so defined that we can all talk the same language. So far it has not been.

PRESIDENT TASKER: It seems highly desirable that we should arrive at a common understanding of what is meant by volume range. Of these three proposals, the last is perhaps the least easily specified, and involves the most opinion and good judgment. The second, likewise, depends upon a factor that is easily misunderstood and is not easy to reproduce promptly with measuring apparatus. It would seem to me, therefore, that the first was the one that ought to be most seriously considered as a standard of reference. In any case, the definition will be more or less arbitrary.

It must be realized that the third concept states what we are trying to attain and what we are concerned about. We are concerned with the ratio between what we dare to put upon the film as a maximum, and what we may put upon it as a minimum. Once having specified the range between the maximum recording signal and the surface noise under some easily specified condition, then all our thinking might be referred to that figure. Consequently, I should like to propose that the first of those be the one adopted.

MR. EVANS: The Sound Committee, in studying the question, felt that our definitions should be consistent with similar definitions in the radio field. Radio engineers have encountered the same problem, so we are trying to determine what, if anything, the Institute of Radio Engineers has done in the way of defining such terms.

MECHANICAL REVERSED-BIAS LIGHT-VALVE RECORDING*

E. H. HANSEN AND C. W. FAULKNER**

Summary.—*Many methods have been applied recently for increasing the volume range of recordings. Some, such as the push-pull system, require mechanical and electrical modification of existing apparatus in order to utilize their advantages. In an effort to produce prints capable of standard reproduction, with increased signal-to-noise ratio, the mechanical reversed-bias method has been used at the Twentieth Century-Fox Film Studios. Briefly, it is a method of reverse-biasing a valve so that the valve aperture is increased by the biasing current to a degree sufficient to prevent clash. Further modification provides for a combination of standard biasing up to a certain percentage of modulation and mechanical reverse-biasing from that point on, resulting in an increase of 8 to 12 decibels over the usual methods in signal-to-noise ratio.*

Recent developments of sound recording and reproduction have indicated a growing appreciation of the necessity for more nearly conforming to the original sound level and frequency range. Wide-range and high-fidelity developments have sufficiently expanded the frequency range to improve the illusion of reality considerably, but no method yet in commercial use provides a volume range of the desired extent. It has been felt that a range of approximately 55 decibels from the surface noise to the peak level would provide a true sound volume perspective.

Since the inception of sound pictures an attempt has been made to achieve expansion and compression of volume by means of the fader, cued by the projectionist. This means is entirely unsatisfactory, due to the requirements of manual cueing, and requires that the operator be able to give his undivided attention to his cues, be alert at every showing, to have a genuine interest in his work, and a sense of showmanship. From sad experience it has been found necessary to produce prints containing therein all the necessary volume variations, and a reproducing system having a capacity sufficient to encompass this range of volume. With reference to the latter, much considera-

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** Twentieth Century-Fox Film Corp., Hollywood, Calif.

tion is being given nowadays to the fact that there are very few houses capable of reproducing even speech levels without some trace of volume distortion. There are many 1200-seat houses in which the maximum undistorted output is less than three watts.

While the studio is vitally interested in reproduction, it must first place its own house in order and provide a negative of optimal characteristics and capacity. In studio production, we find two kinds of mixers: those of the first school believe in setting their own peak levels and allowing sounds from the source to modulate and mix themselves; those of the second group have become afflicted with what is commonly known as the "mixer's itch." Experience has shown it to be possible for both kinds of mixers to achieve excellent results, although it appears that in general those of the former group turn out consistently better pictures.

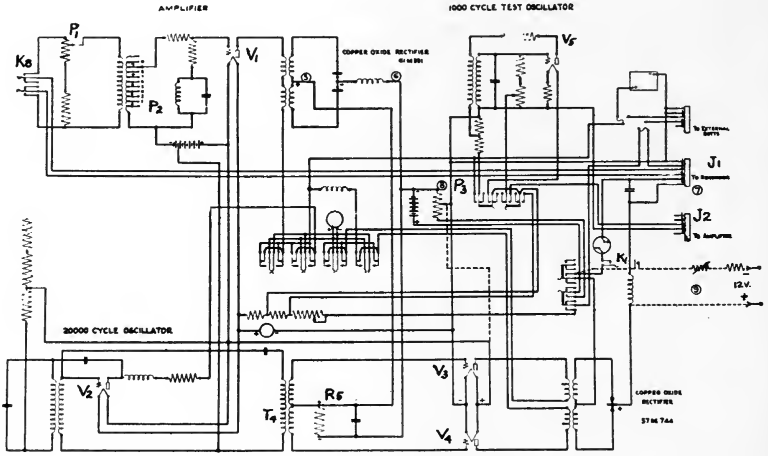

FIG. 1. Diagram of the noise-reduction unit.

It is customary in production to record dialog peaks approximately 10 decibels below clash. This is supposed to be sufficient to take care of dialog peak transients and the volume differential between normal dialog and a brass band, airplane motor, or the firing of a 16-inch gun. Some sounds, of course, are so loud as to be unpleasant to hear, even should the facilities be provided for recording and reproducing them, and we should not care to reproduce them in their original intensities. There is, however, need for a 30- to 40-db. differential between normal dialog and peak volume. It might well be that during the reproduction of an entire picture the peak capacity would be reached for only a few seconds, but the improved effectiveness of the picture as a whole would warrant the greater range.

The limiting factor in standard recording is either that of overshooting the oscillograph armature or the clash of valve ribbons. This happens before photographic and amplifier distortion occurs, and places a psychological handicap upon the mixer. The mixer's attitude is to play safe, and his involuntary muscular reaction is to reduce the level. The optimal arrangement would be to set the mixer at the normal dialog level and allow the peak sounds to reach their limits without restriction. With certain abnormally loud sounds the flattening of the film response curve would be the only safety-valve provided.

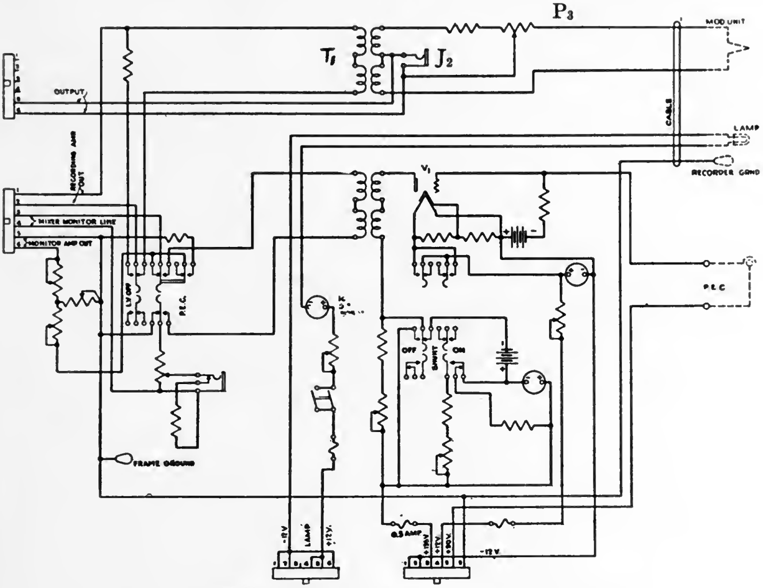

FIG. 2. Wiring diagram of recorder control cabinet.

Many methods have been applied during the past two or three years for increasing volume range of the system. Some of these, such as the push-pull system, require the mechanical and electrical modification of existing apparatus in order to utilize their advantages in theater reproduction. In an effort to produce prints capable of standard reproduction, with increased signal-to-noise ratio, the mechanical reversed-bias method has been used on certain productions at the Twentieth Century-Fox Film Studios. Briefly, it is a method of reverse-biasing a valve so that the valve aperture is increased by the biasing current to a degree sufficient to prevent clash. Further modification provides for a combination of standard biasing up to a certain percentage of modulation and mechanical reverse-biasing from that point on, resulting in an increase of 8 to 12 decibels over the usual methods in signal-to-noise ratio.

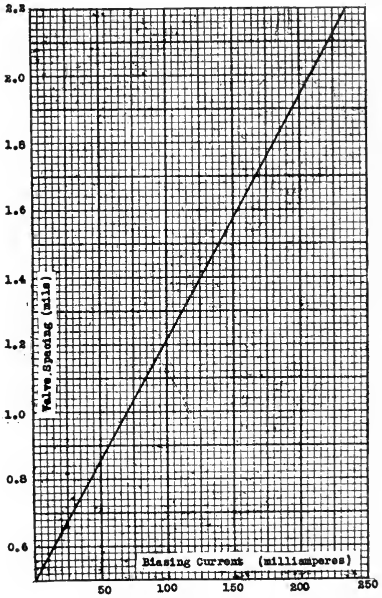

FIG. 3. Valve spacing as a function of the biasing current.

In lining up a standard valve for recording, it might be well to describe briefly the circuit of the noise-reduction unit, as shown in Fig. 1. Four amplifier tubes are used, the fifth tube, *V-5*, being the 1000-cycle test oscillator. An oscillator of the tuned-plate type generating a frequency of 20,000 cycles (*V-2*) is used to feed the push-pull stage, *V-3* and *V-4*, the output of the latter being rectified by the copper-oxide unit to produce direct biasing currents for the valve. The push-pull stage is modulated by the voltage drop across *R-5*, which is derived from a second copper-oxide rectifier in the output circuit of *V-1*. *V-1* is merely a speech amplifier of the conventional transformer-coupled type. The output or biasing current from the copper-oxide rectifier (*57M744*) is approximately proportional to the voltage drop across *R-5*. It will be noticed with reference to the grid circuits of *V-3* and *V-4*, that the polarity of the voltage drop across *R-5* is opposed to that of the bias voltage applied through *P-3*; thus, as the rectified signal voltage across *R-5* is increased, the grids become more positive until at the shoulder of the I_p-E_g curve the a-c. output of *V-3* and *V-4* is zero.

After the main recording amplifiers have been properly adjusted, the 1000-cycle test oscillator is turned on, with a signal of approximately −4 db. applied to the input of the valve transformer *T-1* (Fig. 2). With this signal applied to the valve, a pair of head-phones is inserted into *J-2* and the simplex resistor *P-3* is adjusted until the tone heard is minimal. When this adjustment has been made, the phones are removed and an attempt is made to determine the clash point of the valve. This may be done in several ways, the one most commonly used being to listen directly to the valve. For valves of the permanent magnet type tuned to 10,000 cps., this has been found

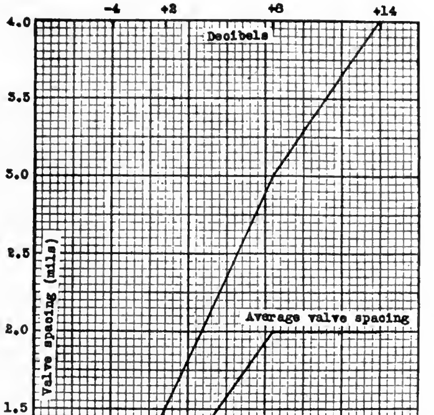

FIG. 4. Relation of valve spacing to biasing current for a 6-db. margin, up to an applied level of +14 decibels.

to be: for the 0.5-mil valve, +2 db.; for the 1-mil valve, +8 db.; for the 2-mil valve, +14 db. The noise-reduction unit is then ready for adjustment.

Assume that the valve is spaced 1 mil, the desired noise-reduction is 8 decibels, and that the margin between signal input and valve spacing is 6 decibels. First, obtain the clash level, which will be approximately +8 decibels. Desiring an 8-db. noise reduction, the input signal is decreased by 8 db., or to zero level, at which point the bias from the noise-reduction unit (*K-1*) should be turned on and increased by means of *P-3* until a second, or biased clash, results. The difference between the original spacing and the biased spacing will determine the reduction of noise, which in this case should be 8 decibels. Letting the bias current flow through the valve, provision should now be made for the 6-db. margin between the signal input and the valve spacing. The original clash level being +8 decibels, an input signal set at +2 decibels would cancel the biasing current 6 decibels below the original level. The cancellation is done by turning on *K-8* and adjusting the gain of the noise-reduction amplifier by means of *P-2* and *P-1*.

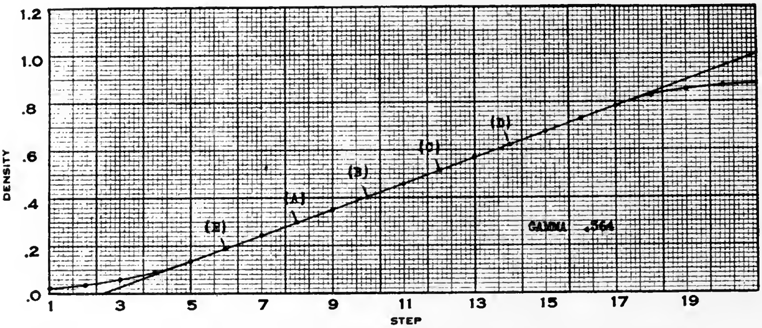

FIG. 5. Negative film characteristic. At *A*, with a 0.5-mil valve, the exciter lamp is adjusted for a negative density of 0.3. As the exposure at any step is 1.4 that of the preceding step, *B* represents the exposure with a 1-mil valve (lamp adjustment remaining unchanged), *C* for 2 mils, and *D* for 4 mils. For a margin of 6 decibels between valve width and signal strength, *E* represents the lowest density used.

In order to modify the noise-reduction system for operation with the reversed valve, referring to Fig. 1, changes *5*, *6*, and *8* were made. By reversing the voltage drop across *R-5*, making it additive to the bias applied through *P-3*, and returning the grids of *V-3* and *V-4* to the positive leg of the filament, we attain the condition of zero, or a slightly positive bias of the modulator stage, *V-3* and *V-4*. Consequently, current flows in the grid circuit of *V-3* and *V-4*, lowering the tube input impedance and, in turn, the impedance looking into *T-4* from the 20,000-cycle oscillator, *V-2*, thus causing a decrease in amplitude of the oscillator output.

When a negative voltage is applied to *V-3* and *V-4*, the tube input impedance increases, causing a decrease in the reflected impedance into the primary circuit of *T-4*, and the output of the oscillator increases. We therefore have the condition that, when the maximum biasing current is required at the valve, the modulator stage, *V-3* and *V-4*, is supplied with a negative bias (voltage drop across *R-5*) of sufficient magnitude to work the tubes at the center of the straight-line portion of the $I_p - V_g$ curve. The impedance reflected into the primary of *T-4* is decreased; the amplitude of oscillation is increased; and a maximum of current, limited by the carrying capacity of the tubes *V-3* and *V-4* of the modulator stage, is supplied to the valve.

Referring to change 7, the polarity of the bias supplied to the valve must be such as to cause the valve to open; hence the reversal of the leads of *J-1*, which are the light-valve simplex circuits.

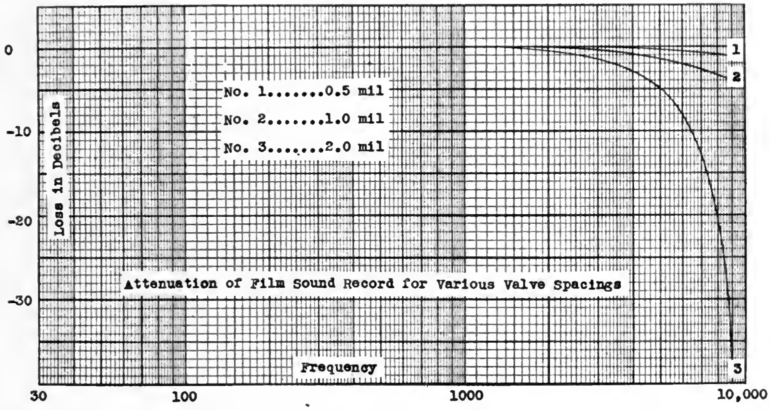

FIG. 6. Attenuation as a function of frequency for valve spacings of 0.5, 1.0, and 2.0 mils.

With this arrangement, as the signal input is increased the amount of bias to the valve is accordingly increased, and the valve spacing will be approximately proportional to the signal input up to the overload point of *V-3* and *V-4*. Provision is made for the 6-db. margin by adjusting the gain of the noise-reduction amplifier, *V-1*, until for any given a-c. signal input to the valve, the bias supplied through the noise-reduction unit will be sufficient to open the valve to a spacing that will accommodate a signal of twice the applied voltage before clashing.

Fig. 3 shows the valve spacing in mils corresponding as to the biasing current in milliamperes. Fig. 4 shows the relation of the valve spacing for a 6-db. margin, with applied power up to +14 decibels. Fig. 5 is the negative film characteristic for a 0.5-mil valve. The exciter lamp is set to produce a density of 0.3 on the negative

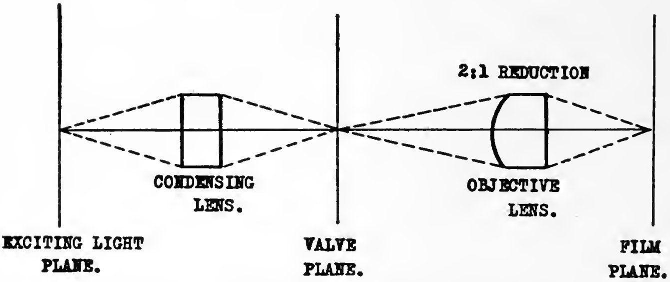

FIG. 7. Diagram of the optical leverage.

(*A*, Fig. 5). Each step is 1.4 times the exposure of the preceding step. Point *B* represents the exposure with a 1-mil valve for the previous value of exciter lamp current; *C* and *D*, the exposure from a 2- and a 4-mil valve, respectively. Using a margin of 6 decibels between the valve width and the signal strength, *E* represents the lowest density used. Figs. 4 and 5 have been plotted up to a level of +14 decibels. However, satisfactory processing is possible with higher levels, showing increased volume ranges over the conventional methods.

Fig. 6 shows the attenuation as a function of the valve spacing, for spacings of 0.5, 1.0, and 2.0 mils. Although the attenuation appears to be serious, in practice the ear does not detect the attenua-

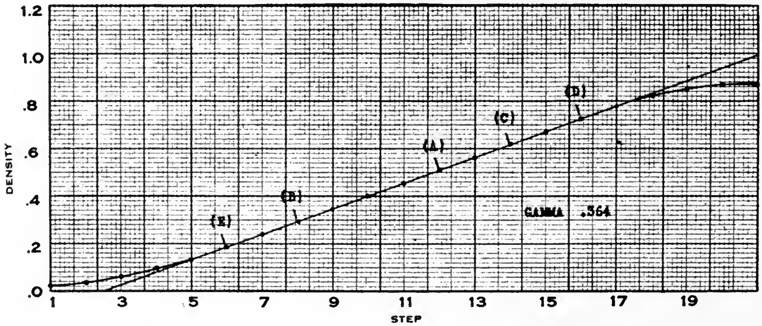

FIG. 8. Negative film characteristic. At *A*, with a 1-mil valve, the exciter lamp is adjusted for a negative density of 0.5. By means of an *A*-battery, the valve is biased for a 10-db. noise reduction (*B*). The bias supplied by the noise-reduction unit being opposite, and more than sufficient to cancel the initial bias, the valve is opened an amount wider than the initial spacing determined by the rectified current from the noise-reduction unit. *C* represents the exposure for a 2-mil spacing; *D*, 4 mils; and *E* represents the lowest density used with a margin of 6 decibels between valve width and signal.

tion as would be indicated by these curves, due to the optical leverage shown in Fig. 7.

It was felt that since the advantages gained through the simple mechanical reversed-current valve were so noticeable, a further increase might result if double biasing were used. In this arrangement reversed bias is reduced to a spacing of approximately 1 mil, and then standard biasing is applied from this spacing down to whatever value of noise reduction is desired. It is therefore possible to achieve both the maximum of standard noise reduction plus the advantage of the reversed bias. In the operation of a double-bias valve the good features of both the standard and reversed bias are used.

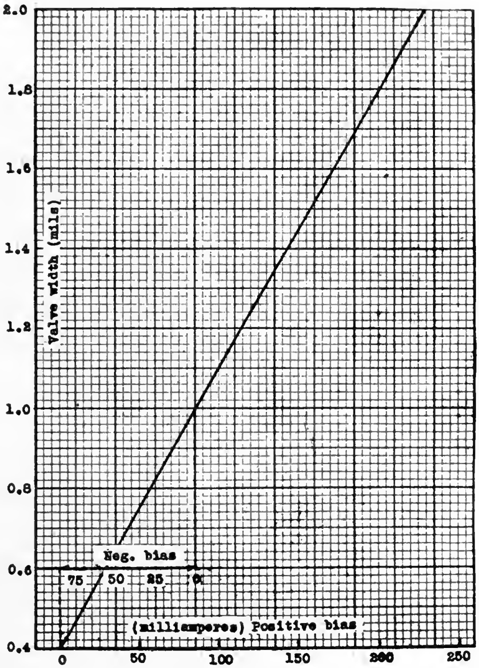

FIG. 9. Valve spacing with positive and negative biases.

Referring to Fig. 1, note *8*, an external battery is used to bias the valve for an 8-db. closure, while the polarity of the bias from the noise-reduction unit is opposite, so as to open the valve. Unlike the normal or standard set-up, the valve does not retain its original opening once it has attained it, with clash occurring when the higher signal is applied; rather, the bias increases with the signal strength up to the overload point of *V-3* and *V-4*, permitting the valve to accommodate a signal of greater amplitude.

Referring to Fig. 8, it will be seen from the negative H&D curve that film distortion will not occur until the valve has been opened to approximately $2^1/_2$ mils and fully modulated. This is a typical negative H&D curve for double biasing. Using a valve spacing of 1 mil, the exciter lamp is set to produce a density of 0.5 on the negative (*A*, Fig. 8). By means of an external or system *A*-battery the valve is biased for a noise reduction of 10 decibels (*B*, Fig. 8). The bias applied by the noise-reduction unit being opposite in polarity and more than sufficient to cancel the initial bias, the valve is opened wider than the original spacing. This spacing will be determined by the amount of rectifier current from the noise-reduction unit. *C*, Fig. 8, represents the exposure from a valve spaced 2 mils; *D*, the ex-

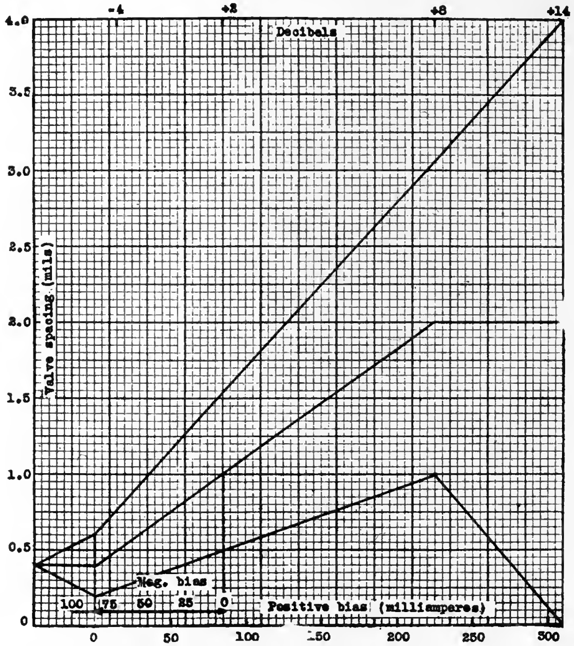

FIG. 10. Valve spacing with negative and positive biases for 6-db. margin, up to an applied level of +14 decibels.

posure from a valve spaced 4 mils; and *E*, the lowest density used with a margin of 6 decibels between valve width and signal.

Fig. 9 shows the valve spacing in mils when positive and negative biases are applied. The normal spacing in this case is 1 mil. Fig. 10 shows the valve spacing in mils plotted against applied power levels up to +14 decibels. In the search for methods of achieving greater levels it must always be borne in mind that an increase in noise reduction is equivalent to a corresponding increase in the load-carrying value of the negative.

In general, the following are the advantages of the double-biased valve:

(*1*) Approximately 10 decibels' higher level on the film than with the standard valve.

(*2*) Less attentuation at the high frequencies for the same modulation of the negative, as compared with that of the reversed valve.

(*3*) Less power necessary than with the reversed valve, for the same value of modulation of the negative.

(*4*) Less distortion from valve bowing, for a given modulation of the negative.

THE MOTION PICTURE THEATER SHAPE AND EFFECTIVE VISUAL RECEPTION*

B. SCHLANGER**

Summary.—*The shape of the motion picture theater should be determined both in the horizontal and vertical sense, chiefly by certain basic factors of the physiology of the eye and the laws of visual reception. Recognition of these factors in designing the theater produces a theater form of minimal depth, concentrating the seating as much as possible with the vertical dimension. Visual acuity and the subtended angles of the viewed image are analyzed as they affect the theater form.*

One of the valuable features of the motion picture lies in the fact that the spectator can, at will, be placed exceedingly close to, or at any desired position in relation to the action upon, the screen, thus transplanting him from the theater to the actual time and locale of the story that is unfolding. This effect is not fully achieved at the present time because of the prevalent forms of the motion picture theater. If the spectator were at the actual scene, the position of the objects in view would be vividly impressed upon him by means of the amount of detail discernible and by the large proportion of the field of view occupied by the object. The spectator in the theater must experience an equally vivid impression. But in the theater the image upon the screen from most viewing points occupies a comparatively smaller portion of the area of the spectator's field of view, less detail is discernible, and, thereby, the original force of the particular scene as the director envisioned it is diminished.

The view of the screen from any seat in the theater should, as nearly as possible, transmit to the retina of the spectator's eye the same picture recorded upon the retina of his eye as though he were at the actual scene, with his eye occupying the same position as the camera lens. The physiology of the eye should be studied to determine whether such correspondence of visual reception be possible, if not from all, at least from almost all, the seats in the theater. In

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** New York, N. Y.

the present theater form, such desirable reception is experienced from a comparatively small number of seats.

More specifically, visual acuity, the geometry of optics, and an analysis of the distinct and indistinct fields of view must be considered in this problem. Lack of recognition of the fundamental physiological aspects of vision in motion picture theater design has resulted in structures in which a major portion of the seating capacity is unsuitable for effective visual reception. Many other factors of secondary importance, such as acoustics and projection, have been recognized and studied with fair success. Yet the more important physiological elements of visual reception have been largely neglected.

It is known that if one sits too far to one side of the screen, the picture becomes distorted. This fault has been apparent, and an effort has been made to avoid such viewing positions when designing the theaters. The factors dealt with in this paper relate more specifically to the ratio of the screen size to the viewing distances. The thesis here will be that too many seats are located too far from the screen for a given size of screen.

The disadvantages of excessive viewing distances are not as apparent to the viewer as is side-seat distortion, except in that the viewer usually tries to find a seat at a distance from the screen that is satisfactory to him; and repeatedly, on subsequent visits, he seeks the same point of view. A chart made to record the locations of the seats chosen by the first half of the audience attending each show, averaged over a number of theaters and a number of shows, would provide an indication of the limits of the viewing distances within which the most satisfactory reception occurs. Such an area can be accurately plotted now that the physiology of the instrument of reception, namely, the eye, is well understood.

To set the limits of the distance, it is necessary first to determine the maximal size of the audience, which must be determined by the maximal size of screen, which, in turn, is determined by the present width of film. If the visual acuity, apparent screen size, and distortion are properly considered in motion picture theater design, the seating capacity, using 35-mm. film, should not exceed much more than 2000 chairs. It might be noted that an increase in the width of the film would not necessarily warrant greater seating capacity, because such increase might be made more for improving the proportions of the picture—making it wider—than for increasing the size of the elements in the screen image. The height of the picture, and therefore the size of its elements, could be and would be the same as it is now. The need of a screen and a width of film to accommodate many more than 2000 seats may be disregarded, as recent statistics on seating capacities have indicated.

The limit of seating capacity is determined by the maximal viewing distance for a given size of screen. As the size of the screen increases, to accommodate increasing viewing distances, the magnification finally causes graininess to appear in the image, and the distortion of the picture seen from areas near the screen becomes worse. The limits of the 35-mm. film are thus determined. It is therefore obvious that it becomes necessary to reduce the viewing distance and the screen size, and endeavor to place the greatest number of seats within the viewing distance so limited. Such an arrangement would minimize the graininess of the image and the side-seat distortion of the theater. Fig. 1 is a longitudinal section of an auditorium, indicating one method of achieving this.

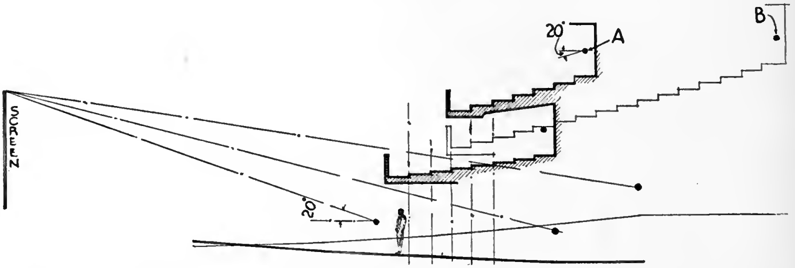

FIG. 1. Longitudinal section of auditorium, showing seating arrangements for (*A*) limited viewing distance, approximately $3^1/_2$ times the screen width; and (*B*) usual arrangement in existing auditoriums, with viewing distances up to 5 times the screen width.

An investigation was made for the purpose of establishing a proper ratio of maximal viewing distance to screen size, of which the visual acuity of the viewer and the apparent size of the screen image to him are the determining factors. This ratio in nearly all existing motion picture theaters ranges from 5 to 7 times the screen width. A ratio of $3^1/_2$ to 4 was chosen in constructing Fig. 1.

Visual acuity is the ability to distinguish fine detail, and is measured in terms of the angle of vision at which the detail in question becomes indiscernible. Helmholtz observed that under best conditions this angle is about one minute and four seconds. Weber fixed it at one minute and thirteen seconds to two minutes and thirty-three seconds, subject to the intricacy of the pattern. More recently, Luckiesh and Moss, and Freeman have made extensive tests taking into consideration the exposure time, the viewing distance, and the relative contrasts. In one of Luckiesh's tests, one minute and fifteen seconds was the limiting angle for a test-object placed at a distance of 320 centimeters from the eye.

The ratios $3^1/_2$ and 4 correspond to limiting angles of 3 minutes, 15 seconds and 2 minutes, 45 seconds, respectively. The angle was determined by selecting very small important details in a number of motion picture scenes and measuring the sizes of such details upon the screen and the distances at which they could still be seen clearly.

It is recommended that a certain margin be allowed for extreme distances, low contrast in the image, and rapid exposures. In such cases the visual acuity angle has to be as great as four minutes. Actual auditorium tests should be made to establish the margin more exactly.

It might be argued that close-up shots in cinematography circumvent the need for great acuity with more distant shots. That is not so, because with the increase in size of the close-up, there is a corresponding increase in the number of details to be discerned. The need for a larger margin for the acuity angle, and correspondingly shorter viewing distances, becomes more evident when it is realized that many important details upon the screen have contrast values of 25 to 50 per cent, and sometimes less. Smaller contrast values, with shorter viewing distances, are far more desirable than unnatural, sharp contrasts used to make longer viewing distances possible.

Ideal visual reception of motion pictures is not achieved merely by limiting the viewing distance for visual acuity only. The visual angle for the viewer, subtended by an image upon the screen, and the "visual" angle for the camera lens, subtended by the object being photographed, should, under ideal conditions, be the same. The field of view in each case must be similarly occupied, so that the proportion of the field of view occupied by the object of interest will be the same when viewing the image of the object upon the screen as it would be if the object were viewed from the lens of the camera.

To achieve such an effect, the viewing distance would have to be limited to an impracticable extent, unless a multiple-screen theater were feasible. Note in Fig. 2, showing horizontal viewing angles, that *A*, at a distance of 3 times the width of the screen, subtends a horizontal angle of 20 degrees, and a proportionate (3:4) vertical angle of 15 degrees. This makes it necessary for the camera lens to encompass an angle of no more than 15 degrees for an image of full screen height, if the viewing distance (in the theater) is about three times the screen width. If the camera is placed closer to the object than that, as it quite often is, the full effect of the close-up is not realized in the theater because of the limited visual angle of the spectator. Although it might be impracticable to duplicate in the theater the angle subtended by the lens of the camera, it becomes necessary to limit the viewing distance to at least that determined by the proposed ratios, as a practicable compromise.

What form of theater would be best adapted to the physical requirements of effective visual reception? Fig. 1 presents a possible method of locating the viewing points within the more desirable limits. One of the aims of this design is to place as many seats as possible in the vertical plane at the particular viewing distance most satisfactory for visual reception. The vertical limits were fixed by placing the highest spectator so that his eye would subtend an angle of 20 degrees, as a maximum, between a line from the eye drawn to the bottom of the screen and a line projected horizontally from the eye. Likewise, the spectator placed lowest in the auditorium was so located that an angle of 20 degrees would be subtended to the top of the screen. These limits are determined by the posture assumed by the spectator in order to enjoy reasonable comfort in viewing the screen. To increase the height within which seats may be placed, the size of the screen, and, correspondingly, the viewing distance, must be increased. The limit, as stated before, is determined by the maximal permissible magnification of the 35-mm. film.

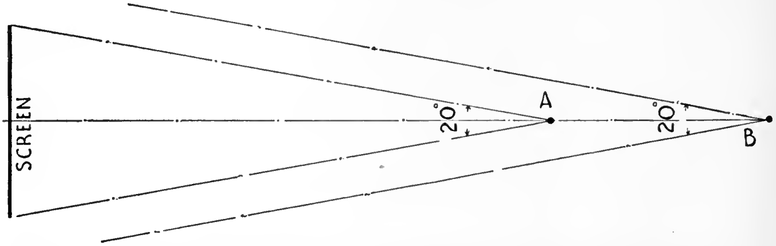

FIG. 2. Plan of viewing angles, showing difference in proportion of screen image subtended from points distant from the screen by (*A*) 3 times the screen width and (*B*) four times the screen width.

The theater form described here can be translated into a feasible structural design. The upper levels of seating are conveniently accessible to the street grade. The highest level of seating occurs where the front portion of the first balcony is usually found. This vertical disposition is made possible by making the orchestra level sufficiently low and yet within the limits of comfortable upward vision.

On the longitudinal section (Fig. 1), the light lines indicate the usual theater form, the depth of which is most unsuitable for proper visual reception. A great many theaters have viewing distances greater than that illustrated in Fig. 1. In the present usual theater, the spectators occupying distant viewing points are forced to become audience-conscious, because a large part of their field of vision is shared by the heads and shoulders of spectators seated in front of them. The improved form shown here is broken into smaller, intimate groups of seats, making the spectator less audience-conscious and permitting the screen to predominate in his field of vision, all of which assists decidedly in creating the desired illusion.

DISCUSSION

MR. CRABTREE: Has the lower floor a reverse slope, in conformance with your previous recommendations, or a half reverse slope?

MR. SCHLANGER: It is an improved, moderately pitched, reversed slope. A number of theaters have been built employing the principle of the reversed slope and have given quite satisfactory results. A slight modification of the original design has been made to correct for the neck-strain experienced in the first few rows.

In the original design, the screen was placed somewhat higher than was later found necessary. A choice had to be made between a high screen, causing upward-looking and neck-strain in the first few rows, completely without obstruction; and a compromise design of a lower screen, eliminating neck-strain, but with a tolerable amount of obstruction. Upon investigating a great number of theaters having the ordinary floor slope, I found that the comparatively low screen level and an intolerable amount of obstruction prevailed.

Two methods of approach can be followed in designing the floor. One is to provide a clear view for each person over the heads of those in front of him; the other is to disregard the need for a clear view and depend upon seeing the screen occasionally between the heads of those in front. The ordinary theater floor is based entirely upon the latter arrangement and, as a result, the view of one-third to the entire height of the screen is obstructed by preceding heads.

The reversed floor described here is designed so that, in the worst instance, no more than one-fourth of the screen would be obstructed by the heads, a degree of obstruction that proves to be tolerable. The pitch is more moderate than that of the usual floor, making walking upon it less difficult. The reversed floor not only reduces the degree of obstruction, but helps to bring more seats within the desirable seating area by making possible desirable upper levels of seating within correct viewing distances.

With limited viewing distances, the ability to obtain a clear view of the screen increases; that is, the greater the viewing distance, the greater the obstruction, as can be demonstrated by holding a finger in front of the eye. As the finger is moved nearer the eye, it obstructs more and more of the view.

With limited viewing distances and the obstruction lessened, the orchestra floor can be rather flat. The rise of the floor as we approach the screen brings those in the front rows nearer the high point of the screen. The ordinary theater floor, starting at a low point and changing direction as we move away from the screen, immediately rises upward, infringing upon the valuable vertical plane of seating. It rises so rapidly that the upper levels of seating are forced upward too rapidly and, as a result, into levels in the vertical plane that are no longer useful. In the proposed plan advantage is taken of space below the ordinary orchestra level, leaving greater upper areas for additional desirable seats.

The suggestion of using this low area is based on the fact that the farther we move from the plane of an object to be viewed, the higher we can see upon the plane without raising the head or using other mechanical means. We just naturally see higher when we move farther away. We can place our seats in the orchestra at points distant from the screen at lower levels than we find in the usual orchestra and yet enjoy an upward vision of the screen that is comfortable. Moving toward the screen the upward vision becomes restricted, and the floor, therefore, must turn upward to compensate for the loss.

At least five or six theaters have been built with reversed floors. The latest is the Pix Theater, at White Plains, N. Y. The first theaters so designed, the Sutton and the Thalia Theaters in New York, and one in Mexico, which latter I have not personally had the pleasure of seeing, have proved quite successful.

MR. CRABTREE: As I understand, you have so arranged the geometry of the theater that a line perpendicular to the screen would lie midway between the upper and the lower floors, dividing the distortion equally between the two levels.

MR. SCHLANGER: Yes. The last head on the orchestra floor subtends an angle to the screen of twenty degrees, chosen as the maximum for comfortable upward vision. The visual angle in the last row of the balcony is such that the spectator can view the picture while his back rests comfortably against the back of the chair. He will not have to bend forward to see downward. In the intermediate level we have practically an ideal condition. We can look straight ahead without the least adjustment of the body.

MR. CRABTREE: What is the extent of the picture distortion in the two positions?

MR. SCHLANGER: The picture distortion in both positions is far less than what is known to be tolerable.

MR. CRABTREE: Also, you have shortened the depth of each balcony as compared with the average theater.

MR. SCHLANGER: Yes. The balconies are at such a distance from the screen as to be within the area recommended in this paper. If they were deepened, they would extend beyond that area. There are therefore two upper levels instead of one, and just so many more seats within the proper viewing limits. The usual upper level in existing theaters is a great deal higher, and should not be compared with this design.

In the usual theater, shown superimposed in Fig. 1 over the proposed design, the seating capacity is approximately the same. In other words, I have succeeded in placing the same number of seats within the shorter, desirable viewing distance, which was the object of this work. The seating capacity is limited only by the properties of the 35-mm. film.

MR. CRABTREE: Is all this calculated upon the assumption that the height of a person above his seat is fixed? I seem always to be unfortunate enough to find a giant seated ahead of me; and when I move to another seat, I find another giant. Would it not be possible, perhaps, to make the seats adjustable so that in such a case a lever could be pulled and the seat raised? It is a very annoying situation.

MR. SCHLANGER: Originally I considered the idea of being able to look over the head of the person in front, and I found a number of disadvantages which I have mentioned before. A certain tolerance has been allowed so that the person ahead would not occupy more than one-fourth of the height of the screen. In most present theaters the whole screen is blotted out completely from the rear rows. In some of the largest theaters in New York having the ordinary type of floor, spectators in the last fifteen or twenty rows can not see the screen without having to keep shifting to see between heads.

MR. CRABTREE: Yes, the public is being cheated if there is any obstruction.

MR. SCHLANGER: I agree. It is a tremendously difficult problem to eliminate obstruction completely on the orchestra floor without resorting to some means of individual chair adjustment, and there is always a practical objection to anything of that sort. In the original reverse type of floor full clearance was possible provided the chairs were built with head-rests to take care of neck-strain, but that was impracticable.

ELIMINATION OF SPLICE NOISE IN SOUND-FILM*

E. I. SPONABLE**

Summary.—*Various methods of eliminating splice noise in sound-films are discussed. A new machine is described that operates upon the punch-press principle, utilizing an opaque cellulose acetate adhesive tape to mask out sound splices.*

The necessity of doing something to eliminate splice noises was realized very early in the practical development of the sound-on-film system. In one of the notebooks of the Case Research Laboratory, dated February 13, 1926, the following appears:

> "Mr. Case has observed and been bothered for some time by the click produced when splices go through our projection machine. Not only does the positive splice make a click but the negative splice sounds when printed through on to the positive. In order to correct this trouble Mr. Case suggests a graded splice; that is, a splice occupying possibly more length, or at least grading in density up to a maximum, and then grading down gradually so as not to give the complete change which will produce a click.
>
> "The same trouble could be avoided by having a shutter operated by the film which would close before a splice passed the slit. This could also be accomplished by having a control on the light itself.
>
> "Mr. Case believes that these suggestions are very important, and will be especially so in sound picture production where it is necessary to put together a large number of scenes. He intends to apply for a patent covering these ideas."

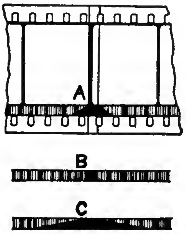

FIG. 1. Paint-out: (*A*) Correct method, quiet; (*B*) too short, will click; (*C*) too long, keeps sound off.

In Case's first experiments he used India ink applied to the gelatin side of the film to produce a gradual change of density at the splice. This was not entirely satisfactory due to the time required for drying after the gelatin was wetted by the ink, and to the ink cracking after it had dried.

A short time later it was found that a quick-drying black lacquer,

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** 20th Century-Fox Film Corp., New York, N. Y.

which softened the film base slightly, could be used to paint out splices by applying it with a small brush to the celluloid side of the film in the manner shown in Fig. 1. This method, which was described in the Fox-Case Corporation's *Movietone Bulletin* of January, 1928, is still in use today, although its execution in some of the commercial laboratories leaves much to be desired. Fig. 2 shows clearly the defects of such a method—more noise is frequently introduced by poor painting-out than would occur with an unpainted splice. Various opaquing materials, and all sorts of stencils, rollers, stamps, and other means for applying such materials have been tried from time to time, but none has worked practically, largely due to uneven covering, or running-under effects.

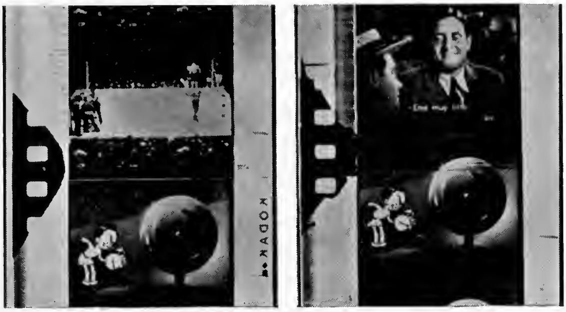
FIG. 2. Good and poor commercial paint-outs.

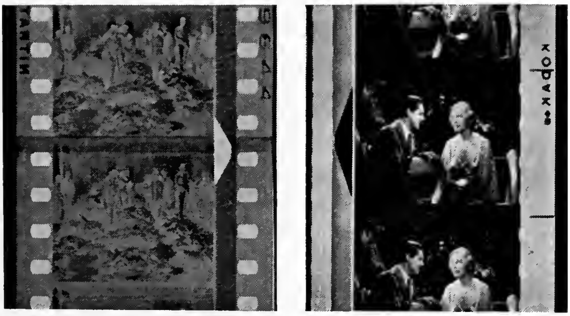
FIG. 3. Punch-out and resulting print-through.

In the early part of 1928 (U. S. Patent No. 1,785,215) a method of handling negative sound splices was devised which consisted in punching out a triangularly shaped portion of the sound-track at the splice

(Fig. 3). When the negative was printed the punch-out would allow sufficient exposure of the print to form a black image, of such shape as to eliminate noise when the film was reproduced. This method has proved very practicable and is still in regular use today although the dimensions of the hole vary somewhat, as shown in Fig. 3. The hole in the negative represents a narrow-based triangular punch; the print was made from one having a longer base. A typical tool for making the punch-outs is shown in Fig. 4, and consists of a punch and die arrangement mounted in a convenient manner for hand operation.


FIG. 4. Hand punch.

In addition to the variations in the dimensions of the triangular hole (Fig. 5), several other shapes of holes are in use at the present time (Fig. 6), all affording fairly satisfactory results when the tools are perfectly sharp and in good adjustment so as to punch cut-outs free from ragged edges. This method of punching out splices has the disadvantage of weakening the film and making it susceptible to tearing or breaking in the printers. Also, as a result of extending the frequency range of the reproducers, the length of the blooped section is not sufficient to suppress the noise entirely unless it is used in conjunction with some sort of cut-off in the low-frequency range.

Another method of handling negative when only sound-track is involved is to use a modified splicer that makes a patch at an appreciable angle to the direction of film travel (Fig. 7). Obviously, the length of the oblique section in the sample shown at the right of Fig. 7 is not

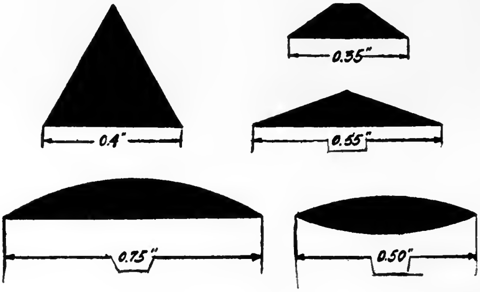

FIG. 5. Dimensions of punch-outs.

sufficient to be of any great practical value. In the case of a film having both sound and picture, a special patch, shown at the left, has been tried, which runs across the film between the picture frames, then travels obliquely across the sound-track, and again perpendicularly to the edge of the film at the sprocket holes. Such a patch requires a special splicer, is difficult to make properly, and hence is not entirely practicable.

Another method of treating splices was worked out several years ago, the general arrangement of which is shown in Fig. 8. A special gate was provided containing a small lamp behind an aperture so positioned that when the light was flashed on, the positive stock would be exposed, through the celluloid, over the sound-track area. The sound negative was notched near the splice, this notch operating a contact switch that lighted the small lamp behind the special printer gate, as well as serving to control the exposure in the sound printing aperture. This type of device produced a variable-density mask such

FIG. 6. Three print-through shapes.

FIG. 7. Angle splices.

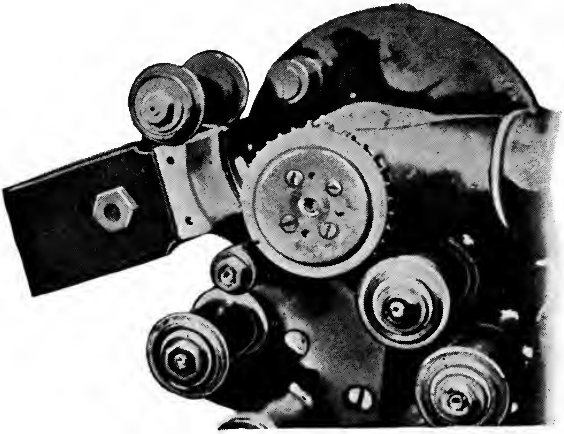

Fig. 8. Patch-flashing gate.

as is shown in Fig. 9. The masking could be controlled both as to position and density as well as length of exposure, by properly choosing the location and the length of the control notch. The procedure, of course, solved only the problem of handling negative patches. Later, as a result of the practice of re-recording practically all original sound into a final negative free from patches, the method was abandoned.

A very satisfactory way of blocking out positive patches was developed and described by Crabtree and Ives,[1] utilizing a special form of opaque patch, shown at the top of Fig. 10, which could be cemented over a film splice by means of the special registering clamp block

Fig. 9. Variable-density mask produced by patch-flashing gate.

shown. Crabtree and Ives thoroughly investigated the requirements and design of the blooping patch and recommended a patch about one inch in length, shaped as shown. Such a patch was found to be practically inaudible above 25 cycles. The main disadvantage of the method is the time required to apply the patches.

Recently, with the availability of opaque cellophane adhesives, it was decided to try to find a way to use this material in some form of punch and die machine. The problem was discussed with T. J. Walsh of the National Ciné Laboratories, New York, N. Y., who had also been considering the problem, and who built the model machine shown in Fig. 11. The machine is operated by means of a hand lever which, upon being depressed, feeds a section of the adhesive material into position, cuts the patch by means of a very accurate punch and die, and finally presses the cut-out portion directly into intimate contact with the spliced film, which has been inserted and registered in position at the base of the machine. The opaque adhesive material is carried upon a perforated paper support in such a manner that the adhesive tape is left free to be cut out by the punch (Fig. 12), the per-

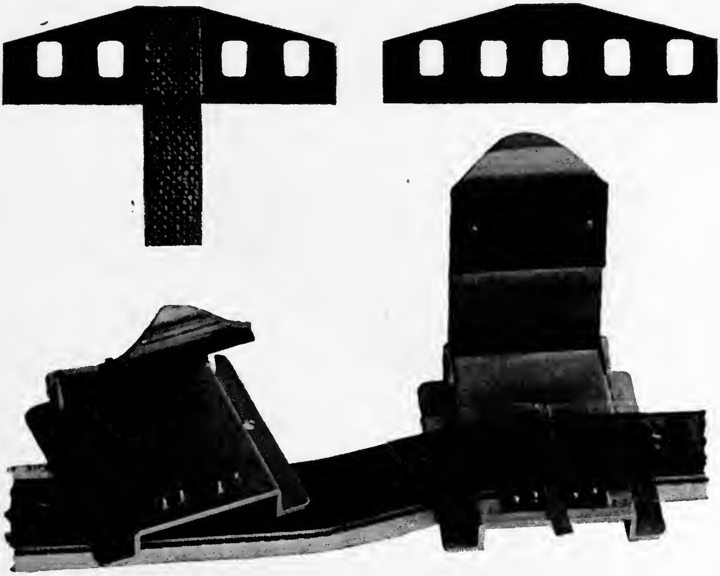

FIG. 10. (*Upper*) Patch with and without finger tab. (*Lower*) Registration block, showing film and patch in position on pins.

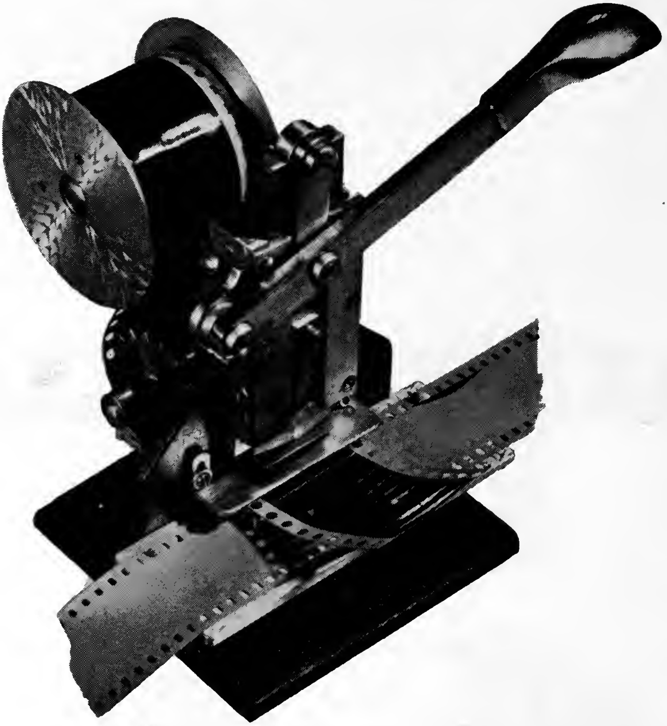

FIG. 11. Machine for utilizing opaque cellophane adhesive.

forated paper preventing successive layers of the tape from sticking, and providing an accurate feeding method. The resultant blocking-out patch adheres firmly to the film (Fig. 13) and, when a sharp punch is used, has smooth, clean edges. The hardened punch and die should maintain their cutting edges, since the material to be cut is thin cellophane or cellulose acetate. It was found that a patch about 1.125 inches long and 3 mils in thickness affords most satisfactory

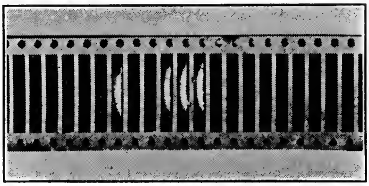

FIG. 12. Paper support used in new machine.

results, and seems to eliminate splice noises of frequency higher than 20 cps.

Tests made in both the East and the West Coast Fox studios indicate that the device will prove practicable and comparatively fast in operation. Plans are being made to produce the machine in quantities and to make it available to the industry.

FIG. 13. Sample of cellophane patch.

REFERENCE

[1] CRABTREE, J. I., AND IVES, C. E.: "A New Method of Blocking Out Splices in Sound-Film," *J. Soc. Mot. Pict. Eng.*, **XIV** (March, 1930), No. 3, p. 349.

DISCUSSION

MR. CRABTREE: Is the patch cemented with a regulation cement, or with an adhesive such as is used on surgical plaster?

MR. SPONABLE: An adhesive tape fairly new on the market, under the name of Scotch Tissue, uses a special cement, the composition of which the manufacturer does not care to disclose. The tape is very adhesive, and is quite satisfactory for re-recordings. It is possible to strip the patch off with a knife, even after it has set for a considerable time. The cement and the opaque material are all self-contained in the carrier roll mounted upon the machine. The thickness of the patch is about 3 mils.

MR. STROCK: In the flashing arrangement, do you rely upon the speed of the film and the resistance of the lamp to provide the gradation?

MR. SPONABLE: Yes.

MR. LESHING: Flashing in the printer would seem quite satisfactory if the possibility of broken splices were eliminated; but the moment the splice breaks, due to the fact that the flashing mechanism is actuated by the notch at the splice, the point of the flash is changed automatically, perhaps to the extent of one perforation hole, or two, or three. For that reason I believe that an adhesive material such as the Scotch Tissue, which can be applied easily, is superior from a practical standpoint to flashing by the notch. The new tissue is being applied as splicing material to keep the film patches from separating during processing.

MR. SPONABLE: Mr. Leshing's criticism of the flashing printer probably has some justification. We felt that with properly made patches, the chances of breaking would be small. Even though a break did occur, the flashed patch was wide enough to cover at least one splicing.

MR. SMITH: Are the patches used on release prints for theaters, or only in the studio at the present time?

MR. SPONABLE: At the present time our principal interest in building the machine was for use in studio re-recording. Undoubtedly it could be very useful in the film exchanges. Incidentally, the main precaution to be taken in using the machine is not to press the lever down when there is no film in it: the patch will be stuck upon the aperture plate and will have to be cleaned off before the machine can be used again.

MR. SMITH: In many prints from exchanges, especially second-runs, the patches are very bad: they are inaccurate, and cause a distinct splice click. In the theater there is no means of getting rid of the click except by lacquering, and in many cases the projectionist has not the time to lacquer so many patches. If the exchanges would use something of this kind, it would be a great assistance.

MR. SPONABLE: I believe it would be satisfactory for that purpose.

MR. CRABTREE: I wish to congratulate Mr. Sponable on revealing this mechanism, with the thought that probably every one here has some equally valuable gadget which could be described for the benefit of the members.

PRINCIPLES OF MEASUREMENTS OF ROOM ACOUSTICS*

E. C. WENTE**

Summary.—*The acoustic characteristics of a room can in great part be evaluated from a knowledge of the rate with which sound in the room dies down when emission from the source ceases. The physical principles underlying the relationship are briefly discussed. It is shown by specific examples that we can obtain valuable additional information about acoustics of a room by recording the sound level at one or more points in the room when the frequency of the sound is continuously varied.*

The function of a motion picture sound system is to transmit an acoustic facsimile of sound generated in a studio to an audience in a theater. This transmission occurs over a series of acoustical, mechanical, optical, and electrical paths, distortion along any one of which will impair the quality of the received sound. The distortion along any part of the route, except those from the source to the microphone and from the loud speaker to the listener, can be determined from a measurement of the transmission efficiency at a number of discrete frequencies distributed throughout the audio-frequency range. Transmission along the acoustic paths is of such a totally different character that here a measurement of such type is of no practical value. For the proper adjustment of the acoustical paths reliance has been placed principally upon aural judgments. We can tell something about the character of sound transmission within a room if we know its reverberation time,† or, what is equivalent, the rate of decay of the transient tone when a steady tone is interrupted at the source. But whatever the reverberation time may be, the quality and level of the sound at different parts of a room may vary between quite wide limits. The determination of the acoustics of a room by measurement of the reverberation time is analogous to the determination of the characteristics of an electrical transmission line by

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.; re-presented at the Fall, 1935, Meeting at Washington, D. C.

** Bell Telephone Laboratories, Inc., New York, N. Y.

† This is the time required for the average sound energy initially in a steady state to decrease to one-millionth of its initial value.

measurement of the transient current at the receiving end when a voltage is interrupted at the sending end, a method sometimes used before convenient electrical audio-frequency oscillators became available, but which is not nearly so satisfactory as a measurement of the transmission *vs.* frequency characteristic.

Transmission of signals over an ordinary electrical line differs from the transmission of sound between points in a room in two important respects: the transients are of much longer duration and, because of the fact that the air in a room is capable of oscillating at an exceedingly large number of different resonant modes within the audio-frequency range, the transient oscillations have practically the same frequency as the steady-state tone. It is for these reasons that measurements of transient oscillations have, on the whole, been of more practical value in the study of the acoustics of rooms than in the study of the characteristics of electrical systems. Since data on transient oscillations have only a limited value even in the case of sound in rooms, while a measurement of the transmission *vs.* frequency characteristic has been found to be a convenient and accurate method of evaluating the practical performance of an electrical system, it is worth while to investigate the possibilities of determining the character of sound transmission between points in a room by a more direct method.

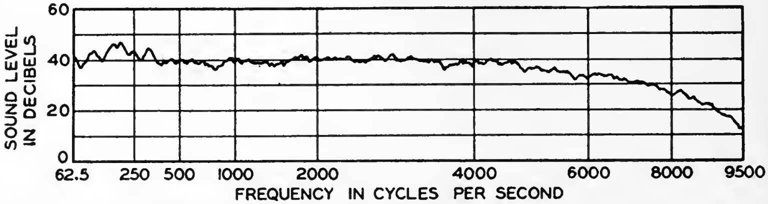

FIG. 1. Recorded frequency characteristic of sound transmission in a room when the frequency is varied rapidly.

A few measurements will convince any one that, in general, no useful information can be obtained from measurement of the transmission at a number of discrete frequencies, for the values will be found to vary by many decibels with only a slight shift in the frequency. More practical results are obtained if the instantaneous pressure levels are recorded while the frequency of the source is varied continuously. The high-speed level recorder, previously described, is particularly suitable for making such records. The method of procedure in these measurements is to generate at one point in a room a tone of constant strength, but varying continuously in frequency, and record at a second point the sound pressure level by means of a microphone and the level recorder. When the recorder is set to operate at low speed, the readings represent the levels of the power averaged over a relatively long time-interval. If, then, the frequency is changed rather rapidly during the recording, the readings will represent levels of power averaged over a relatively wide frequency-interval. Fig. 1 shows a transmission curve obtained between two points in a room under these conditions. The frequency was varied at a rate such as to cover the whole designated range in about $1^1/_2$ minutes. A transmission characteristic of this type will show whether speech or music transmitted between the two points will have the proper balance between the high- and the low-frequency components. If the high frequencies predominate, the sound will be characterized by shrillness; and if the low frequencies overbalance, the sound will have a muffled quality. Other quality characteristics are indicated when there is a rise or a depression in the transmission curve at

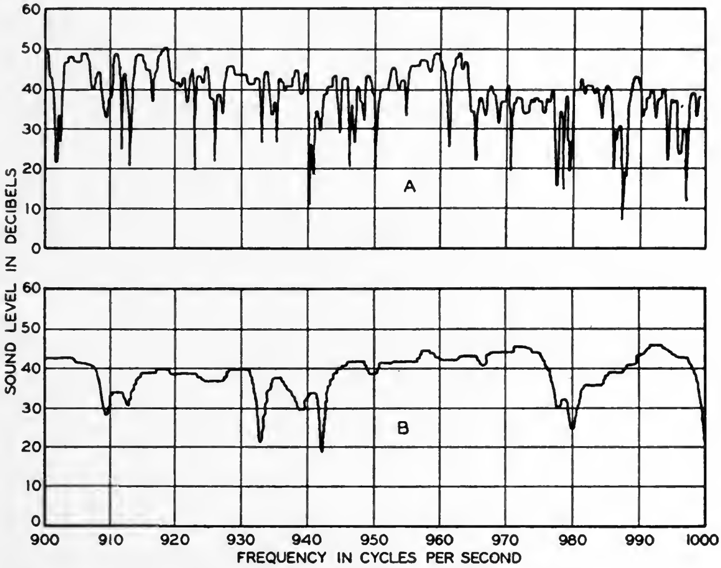

FIG. 2. Recorded frequency characteristic of sound transmission in a room when the frequency is varied slowly: (*A*) live room; (*B*) damped room.

intermediate frequencies. Similarly, measurements in the studio can show something about the character of sound reproduction that would result from various placements of the pick-up microphone.

The transmission curve obtained in the manner just described does not tell a sufficiently complete story to enable us to say whether the transmission between the sending and receiving points for speech or music will be the best possible, or even satisfactory. As far as we can tell from these curves, the room might be entirely too dead acoustically for music, or so live that received speech would be quite unintelligible. Nevertheless, if records taken in this manner show an improper balance, we are safe in concluding that transmission over the measured path will not be satisfactory.

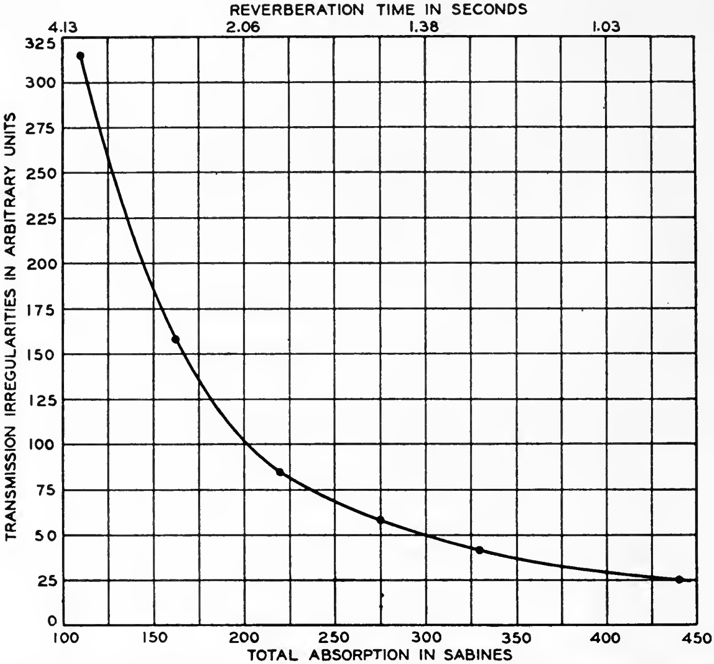

FIG. 3. Relation between irregularity of transmission *vs.* frequency characteristic and reverberation time; capacity of room, 10,000 cubic feet.

Now let the operating speed of the recorder be set to a high value and the frequency be varied slowly while the positions of the microphone and the loud speaker and other conditions are kept unchanged.

Under these conditions the recorder will indicate levels of sound pressure averaged over a small frequency-interval. A portion of a curve so obtained is shown in the upper part of Fig. 2. The frequency range here given is only 100 cycles, extending from 900 to 1000 cps. Although the total change in frequency is only 10 per cent, we find that the curve has innumerable peaks and valleys and that the transmission varies through a range of at least 40 decibels. If, upon measurement, we should find any part of an electrical communication channel to have a characteristic as irregular as this one, we should probably conclude that the system would be incapable of transmitting speech intelligibly. As a matter of fact we should be correct in our conclusion, for this curve was taken in a room that was acoustically so reverberant that it was almost impossible to carry on a conversation between the sending and the receiving points.

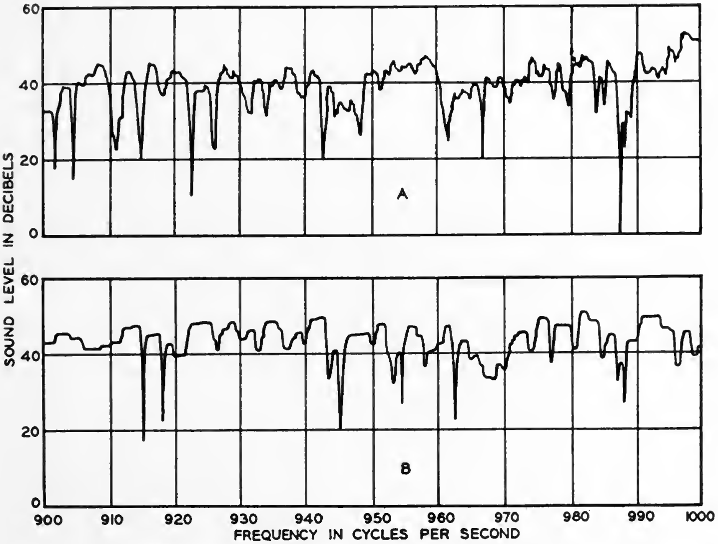

FIG. 4. Transmission *vs.* frequency characteristics to live and to dead parts of a room.

Following these measurements the room was given an acoustic treatment by the introduction of sound-absorbing materials such that the transmission as judged by aural observation was practically ideal. All other conditions were kept the same. The transmission characteristic now obtained over the same frequency range is shown in the lower part of Fig. 2. It will be noted that there are relatively few large dips and that the number and extent of the small irregularities are greatly reduced. The change in the reverberant quality of the room is thus seen to be easily observable from the change in the character of these transmission curves. This change in character can be measured and related to the reverberant quality of the room, or, more accurately, to the reverberant quality of the sound transmission between any two points within the room. One method of evaluating the degree of irregularity of the curve in a given frequency-interval is to take the sum of the pressures of all the minimum points and subtract the result from the sum of the pressures of all the maximum points. In Fig. 3, values so obtained for a 100-cycle band-width are plotted against the reverberation time of the room. The observed points are seen to lie well along a smooth curve.

We might well ask, if there is such a close correlation between reverberation time and the degree of irregularity in the transmission curves, why not simply measure the reverberation time, which can be accomplished within a few minutes by means of the high-speed level recorder. The values plotted in Fig. 3 were obtained in a room in which the sound was fairly uniformly distributed, and both loud speaker and microphone were as far removed as possible from the neighborhood of absorbing surfaces. The reverberation time when measured at various points in a room will have about the same value, for it is determined primarily by the rate of decay of the sound density averaged throughout the whole room; but the degree of irregularity of the transmission to different points in the room can vary markedly, as it depends upon the configuration of the room and the distribution of the sound-absorbing surfaces. The difference is illustrated by the curves of Fig. 4, which were obtained with two different microphone placements in the same room. For the upper curve the microphone was located in a part of the room where most of the surfaces were acoustically hard; and for the lower curve, in a part of the room where the absorption was relatively high. Measurements of the reverberation times at the two points would yield the same value although the forms of the decay curves, which could be determined with a high-speed level recorder, might show characteristic differences.

The reverberation time of a room is independent of the directional characteristic of the loud speaker used as the source of sound. The character of the sound received from a loud speaker in an auditorium does, however, depend upon its directivity. By measurement of the degree of irregularity in the transmission curve, with a particular loud speaker set in a particular way, a much better idea is obtained of the reverberant quality of the sound that is received when the loud speaker is used under the same conditions for the reproduction of speech or music. Similarly, with the recorder set to operate at slow speed, curves taken at various parts of the room with a particular speaker set-up will show the levels and the degree of balance between the high and the low frequencies of speech or music received at various parts in an auditorium.

Various other acoustic effects may be determined from transmission curves. When a microphone is placed near a reflecting surface there will be noticeable interference between the direct and the reflected sound, which may give to the reproduced sound a muffled quality. The lower curve of Fig. 5 is a transmission curve taken at a slow recorder speed when a reflecting surface was placed near the microphone. The difference in path between the direct and the reflected sound was about 15 inches. The upper curve was obtained under similar conditions, but without the reflector. A comparison of the two curves shows that the reflector produces periodic variations in the transmission, which must have a noticeable effect upon sound quality.

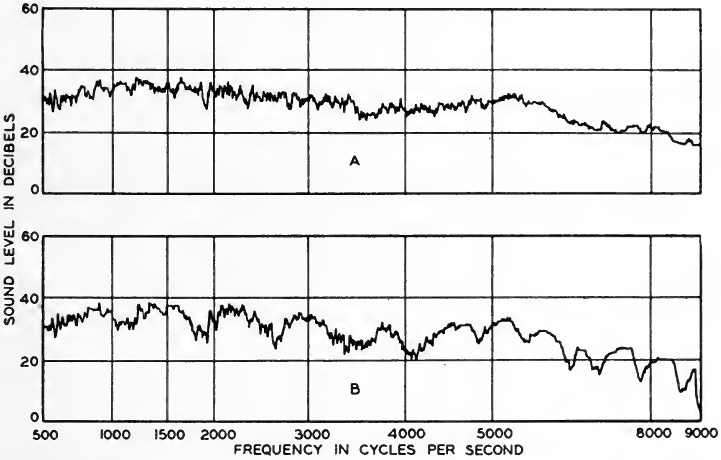

FIG. 5. Transmission *vs.* frequency characteristic between points in a room when a reflecting surface is placed near the microphone.

Although the curve of Fig. 2(*B*), which is representative of a room having good acoustic characteristics, is relatively smooth when compared with that of Fig. 2(*A*), the transmission characteristic is much more irregular than that of most electrical communication channels. The fact that speaking conditions are good in spite of these irregularities is to be explained partly by the nature of speech, which is never sustained sufficiently long to set up a steady-state sound field, and partly by a phenomenon in binaural hearing. Because of the spatial separation of our ears, the sound pressures at the two ears will, in general, be different both in magnitude and in phase. If transmission measurements are made with two microphones at the receiving end connected in series and separated by the same distance as

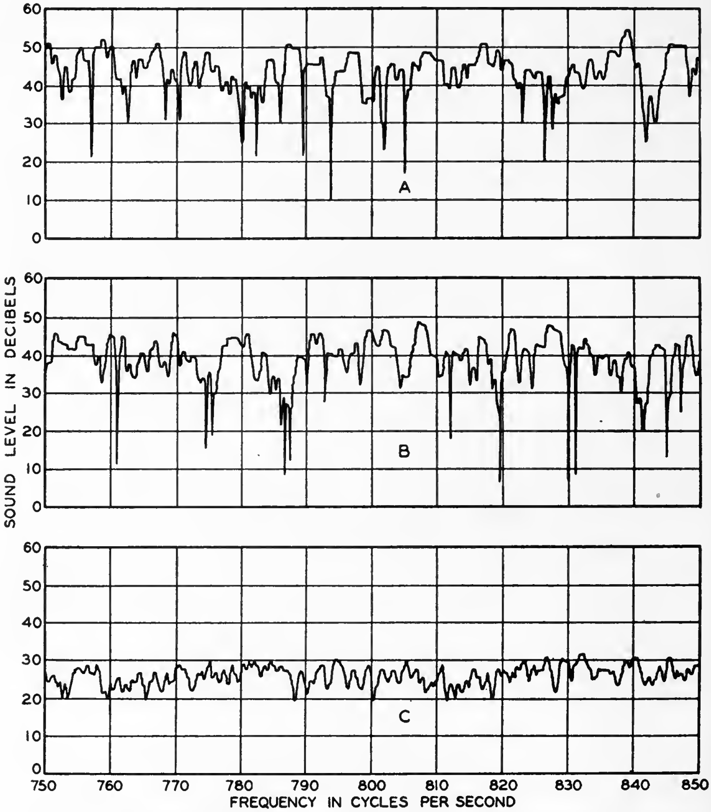

FIG. 6. Transmission *vs.* frequency characteristics under various receiving conditions: (*A*) single microphone; (*B*) six microphones connected in parallel; (*C*) six microphones, each provided with rectifier; output circuits of rectifiers connected in series.

our ears, we shall find that the transmission *vs.* frequency relation is as irregular in character as it is when the measurements are made with a single microphone, because the resultant voltage is proportional to the vector sum of the pressures at the two microphones. It is an experimental fact, however, that the loudness sensation is independent of the phase relation between the pressures at the two ears. If, for instance, the two ears are stimulated by sound pressures of the same frequency, the loudness is the same when they are in opposite phase as when they are in phase. We can, therefore, more nearly simulate binaural reception in the transmission measurements by using two microphones, each provided with a rectifier, the output circuits of which are connected in series to the level recorder; for in this case the resultant voltage will be practically independent of the phase relation of the pressures at the two microphones. The contrast between binaural and monaural reception is accentuated if the measurements are made with a greater number of microphones. The upper curve of Fig. 6 shows the transmission characteristic obtained when a single microphone is used at the receiving end. The middle curve was obtained when the single microphone was replaced by six microphones connected in parallel. The irregularities in the transmission characteristics are seen to be of the same order of magnitude in the two cases. The lower curve was obtained when each of the six microphones was provided with a rectifier and the output circuits of the rectifiers connected in series to the level recorder. This curve is obviously smoother than either of the other two, from which we conclude that in going from monaural to binaural listening in a room, the effect is similar to that produced by a reduction in the reverberation time of the room. However, comparison between Figs. 2(*B*) and 6(*C*) shows that the reduction in the irregularities obtained by increased absorption and by multiple microphones with rectifiers is not exactly of the same character: in one case the rate of decay of sound in the room is altered and in the other it is not. It is well known that when sound is reproduced by microphone and loud speaker, the reproduced sound has a more reverberant quality than when perceived directly by binaural listening in the source room. To reduce this quality it has been common and good practice to increase the damping of the source room beyond the optimal for direct listening. It is, however, not possible by this expedient to get objectively quite the same change in the reverberant quality as is achieved subjectively by binaural hearing.

SERVICING SOUND MOTION PICTURE REPRODUCING EQUIPMENT*

C. C. AIKEN**

Summary.—*An outline of the problems encountered in theaters following the installation of sound equipment, and the determination of standards of performance. The methods and value of gathering experimental data on the operation of equipment in the field, both for servicing and laboratory practice, are discussed, as well as the effects of variations in recording and in the tastes of the public, both from the exhibitors' and the public's point of view, and the effect of intelligent servicing upon the box-office.*

After sound motion picture reproducing equipment is installed in a theater, the following problems are faced:

(1) Maintaining high-quality reproduction.
(2) Avoiding faulty operation and failures.
(3) Adjusting to changing recordings.
(4) Adjusting to changing standards.
(5) Modernizing when feasible.
(6) Gaining experience leading to further improvement.

The maintenance of high-quality reproduction depends largely upon the same factors that are involved in design:

(*a*) The beam from the exciter lamp must be uniform, steady in intensity, of the proper size, and vibrationless.
(*b*) The movement of the film must be free from variation in linear speed, weaving, or fluttering.
(*c*) The electrical system must be free from extraneous noise or distortion, and must have sufficient amplification and a proper frequency response characteristic.
(*d*) The conversion from electrical impulses to sound waves must be without extraneous noise or distortion.
(*e*) The sound waves must be directed so as to provide uniform results throughout the auditorium, without allowing the room itself to introduce objectionable factors.

The standards of performance and the methods of measuring items (*a*) to (*d*) are determined in the laboratory in connection with the design. By extremely close contact between the field and the labora-

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** RCA Manufacturing Co., Camden, N. J.

tory groups, the initial standards and methods and the subsequent changes are made known and put into operation in the field.

The final criterion of quality is the human ear; but among various persons the response of the ear varies enormously. Audiometer tests show a variation of as much as 40 db. among individuals. For a given person, the ear responds differently from hour to hour. To avoid having such variation introduce inconsistencies, the standards set up in the laboratory, in so far as possible, are expressed in terms of objective measurements rather than subjective sensations.

In many cases, the objective laboratory methods have been found to be directly applicable to field use, providing accurate, stable standards for the maintenance of high-quality reproduction. In cases when the ear must be relied upon without the aid of objective measurements, it is necessary to devise special tests by means of which defects in reproduction are caused to be accentuated so that the trained ear can readily detect them regardless of the listener's state of fatigue. In this respect it is important that the field engineer develop an acute sense of hearing by long and continuous training. He must have an excellent standard of comparison and must have had long experience listening to reproduction under many conditions if he is to be able to diagnose equipment accurately to determine whether it is in the best of condition or not.

The field practice to be followed in correcting faulty functioning and failures is determined by experience. The proper procedure is the one that works best by actual test. Systematic accumulation of experience by a large field force in thousands of theaters forms the best possible basis upon which to lay the foundations for these procedures. In the same way that the design of equipment changes from year to year as new and better methods are developed, field procedures go through an ever-improving evolution.

Closely allied with the application of field experience to field practice is the application of field experience to engineering and research. Theory and practice are prone to diverge unless theory is constantly checked against actual results. The sound motion picture art can not develop at the speed it should unless it takes full advantage of its experience. By watching the leaders of the industry, smaller companies are prevented from diverging too far from the path of sound progress, but for the good of the motion picture business as a whole, the larger companies may not neglect to follow the products of their development.

The recordings of some producers are lacking in the bass; others over-emphasize the bass notes and in some the high-frequency response is so garbled as to make it necessary to reduce the highs. As a rule, a satisfactory compromise best suited for the product being shown at the time can be found. But for best performance, changes in the reproducer characteristics are required to be made when the majority of features shown in a theater are obtained from a different producer or when a change is made in the recording characteristics.

Fads introduced in the march toward perfect reproduction carry us too far, first in one direction and then in another. At one time popular opinion required crisp speech of optimal intelligibility; and, at another time, booming, roaring, low-frequency response was demanded. As a matter of good business policy it is necessary to adjust the theater equipment in accordance with the prevailing tastes, and to change them as the tastes vary.

In spite of, or, perhaps because of, the vicissitudes of the show business, progress has been rapid. New tastes, new developments, new requirements have made obsolete in a few years the early theater equipment (and should have made obsolete much of the recording apparatus), demanding either the purchase of new and modern equipment or a major and almost equally expensive though less effective renovation of the old equipment. As improvements become available, they can, and should, be made in order that the existing installations may be kept as modern as possible.

So far the problem has been viewed largely from the standpoint of the technician. Exhibitors are interested in the problem from an entirely different standpoint: that of dollars and cents. Here is the problem of expressing an intangible "quality of reproduction" in terms of tangible "box-office receipts." The many variables, *e. g.*, entertainment value of pictures shown, general business conditions, amount and kind of advertising, *etc.*, make a quantitative analysis impossible or inaccurate. Certain facts can, however, be established from which to draw conclusions, and by checking such conclusions against a sufficiently large number of experiences, determine their accuracy.

Most important of all factors to the exhibitor is the maintenance of high-quality reproduction. In every audience there is an increasingly large percentage of music lovers and critical listeners. Rarely do they analyze the sound equipment when it is "off color," but rather do they say, "I did not enjoy that picture," or "Her voice is not so good," blaming the actor or the producer and discouraging their friends from attending the theater. This reacts to the detriment of not only the one exhibitor, but slightly "off color" sound in neighboring theaters can cause a general degeneration of interest in pictures and adversely affect the attendance at all theaters. An exhibitor should pray, "Let my competitor have *obviously poor* sound or *very good* sound, but let him *not* have *fairly good* sound which will eliminate the thrill of a glorious voice."

The experience of many exhibitors has proved that music lovers and critical listeners are found as frequently in the poorer districts as on Broadway. Experience has proved, also, that a decrease of attendance occurs as a direct result of imperfect tonal quality. Critical listeners and music lovers are the first to lose interest. The poorer the quality the larger is the number of patrons affected. Many patrons will have lost their show-going habit before noticeable dissatisfaction becomes evident.

We have already named the factors that enter into the maintenance of high-quality reproduction. Projectionists have risen splendidly to the difficult job of operating and caring for reproducer apparatus so as to minimize the possible change of quality between service calls. That such change of quality does occur is attested by the fact that no manufacturer of sound motion picture apparatus has long existed who did not set up and maintain a policy of periodic service. From the exhibitor's point of view the bankruptcy of a manufacturer is sad; but the exhibitor is much more concerned with the fact that the *immediate* cause of the bankruptcy lies in the theater, and not in the factory.

Because of the impossibility of expressing the subjective quality of sound in per cent, the discussion thus far has been qualitative, not quantitative. Quantitative study can be made by comparing the cost of routine service against the loss in box-office receipts occasioned by impaired quality of reproduction. If the loss in box-office receipts just balances the investment in a periodic service call, the result of the investment is increased satisfaction, security from interruption, and peace of mind for the exhibitor for no net change in his finances. If the period between routine calls is too great, the decrease in box-office revenue exceeds the cost of additional service, and the reputation and net profit of the theater will suffer. A surprisingly small percentage increase in daily attendance is required to balance the cost of periodic service.

VISUAL ACCOMPANIMENT*

R. WOLF**

Summary.—*The principles of producing "Visual Accompaniments" to musical renditions for the theater are briefly described, as follows; (1) natural scenes for portraying the "musical mood" of the musical composition; (2) the changing and blending of beautiful paintings to interpret the mood, known as the Savage Method; and (3) the use of abstract color forms as a means of interpretation. The technic followed in applying the two latter methods is described in detail.*

In the days of the silent motion picture it was customary to furnish background music as an accompaniment to the picture. In the larger theaters using orchestras, it developed quite naturally that the orchestra opened the performance with a musical composition played with the house fully lighted and the curtain down; in smaller theaters very frequently only a piano was used for this purpose.

With the advent of sound pictures, however, there developed a general tendency to depend upon the picture and its accompanying sound alone. Spoken dialog became all-important, and the musical accompaniment was eliminated. This is unfortunate, because music has a universal appeal. Occasionally, attempts have been made to supply this lack of music from records unaccompanied by visual action, but this has been found to be unsatisfactory to the audience.

Believing that good music has a place in the motion picture theater program, the work described below was undertaken. It has been designated by the broad title of "Visual Accompaniment." The favorable audience reception to the results of this work, to our mind, has justified our expectations. This accompaniment is somewhat abstract in its nature and is determined by the music, unlike the usual sound picture in which whatever music is used is dictated by the action. To meet the needs of the motion picture theater, basically, this means the creation of a motion picture film embodying excellent sound recording of a suitable musical composition, accompanied upon

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* Presented at a Meeting of the Atlantic Coast Section at New York, N. Y., Jan. 9, 1935.

** Electrical Research Products, Inc., New York, N. Y.

the screen by a visual interpretation in mobile color. Visual accompaniment films, as described in this paper, can be used advantageously by any properly equipped motion picture theater.

The interpretation of music in color is by no means new. Considerable work in this field has been done from time to time. The first comprehensive treatment of this subject is probably contained in a book, *Experiments Concerning the History of Harmony in Painting Generally and Color Harmony Specifically, with Comparisons to Music and Many Practical References*, by Johann Leonard Hoffman, published in Halle in 1786. In 1894, Alexander Wallace Rimington constructed an apparatus for color accompaniment to music. Other modern investigators of this subject include H. Beau and Bertrand-Taillet, Herman Schroeder, Hans Bartolo Brand, Emil Petschnig, Alexander Skrjabin, Alexander Laszlo, and many others. Skrjabin designed a color piano and wrote special compositions for this instrument, of which his *Prometheus* was performed in New York in 1916; be it said, however, with little public success. Even now there is in New York a school that conducts a regular course in the relationship of music and color. Considerable work is also being done at present with color organs, with which an individual performer gives his impressions in color of suitable musical compositions.

However, all these efforts are concerned primarily with the combination and interpretation of music and color alone, giving little, if any, regard to form. In our development work we have found it advisable to pay some attention to form. As already mentioned, we begin in each case with a well known musical selection, recorded with exceptionally good quality, and produce upon a motion picture film a visual accompaniment in one of the following three ways:

(*1*) Natural scenes are used to portray the 'musical mood' of the composition. For example, Mendelssohn's *Fingal's Cave* is interpreted by natural scenes of sea and rocky shore, depicting, in the ever-changing form of the waves, the mood of the music. The photography, of course, is in natural color.

(*2*) Beautiful paintings constantly changing and blending are used to interpret the mood of the music. This method, conceived by the eminent painter and sculptor, Eugene F. Savage, will, in this paper, be referred to as the "Savage Method." The basis of this treatment is to create motion pictures in natural colors from miniature stage sets which are correct, not only from the standpoint of composition and color, but also as works of high artistic merit. The body of the paper is devoted to discussing this method in detail.

(*3*) Abstract color forms are used to interpet the musical composition. This will be referred to as the "Abstract Method," and while described, will not be discussed in as much detail as the "Savage Method."

MUSICAL MOODS

Pictures made by the method described under (*1*) have been released commercially under the title of *Musical Moods*. This method is the most conservative of the three to be described. A suitable nature scene is photographed in natural colors. Considerable extra footage is taken and the final picture is the result of careful cutting as well as of depicting a scene appropriate to the music.

THE SAVAGE METHOD

The description of this method will be based upon the visual accompaniment to Schubert's *Unfinished Symphony*. There is no authentic record of the composer's visual conception of this work. Program notations by eminent musicians and critics covering many years have agreed upon some symbolism, however, although in very general terms.

The life and early death of Franz Schubert come to mind in the *Unfinished Symphony* and are carried through the visual accompaniment:

> "At the opening chords, or narrative, we are led into a gracious and beautiful world of mountain heights and castles, mirrored in the depths of a river, which is seen beyond a sculptured balustrade and varied foliage. With the romantic love *motif*, two figures appear, seated under a spreading tree by the water's edge. The warm and engaging atmosphere of the setting gives way to a somber tone, the rapture of the music is brusquely interrupted, a sudden storm overwhelms the scene. As it clears, the man stands by the sea gazing at the heights as though challenged by them. Two muses move across the face of the moon above him, encouraging his aspirations.
>
> "The scene changes to one of sheer barren heights. He has given all and gained the heights, but is stopped by a trumpet blast sounding his mortal and inexorable doom. A storm of stressful and clamorous music whirls about him, lightning threatens him from above, waves reach for him from below, until a rainbow appears with its promise of respite.
>
> "The scene fades to a pastoral valley. The man kneels by the river; his strength is spent. The muses appear again, and give direction to his destined end. In the last scene he is prone, overwhelmed by his efforts and vanished hopes. He lies upon the brink of a chasm into which the river is falling. The ascending vapors carry his last aspirations heavenward; the muses gather over him in the vapor, and with the brusque chords of the closing music, take him with them upward and out of the picture."

The music, as is always the case, is first recorded and carefully timed. Significant passages are noted and timed. In this way, a general layout sheet is compiled. It should be noted here that no attempt is made at close synchronization of music and action. However, a few key points in music and action are made to synchronize generally. Fig. 1 shows the general layout sheet. Finished water color sketches of the important scenes are then made.

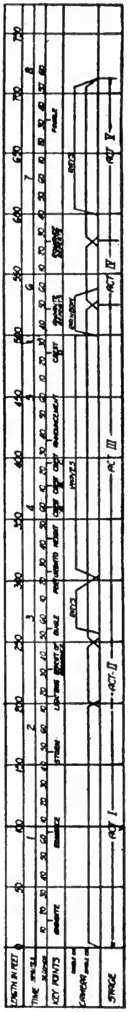

FIG. 1. General layout for visual accompaniment to Schubert's *Unfinished Symphony.*

The preliminary work having thus been completed, it is necessary to prepare the settings for the miniature stage. This stage is shown schematically in Fig. 2. A set of planes are provided, lettered *A* to *F*. In the actual stage, these planes are oil paintings upon acetate sheeting. Care must be taken in laying out these paintings from the original sketches so that the proper perspective, which necessitates changes in dimensions as the planes progress up-stage, is taken into consideration.

Moving clouds and scenes are painted upon long strips of acetate sheeting and wound upon rollers. These rollers can be mounted so as to move the painting either vertically or laterally. Movement, as well as its acceleration and deceleration, is controlled by mechanical means. The fact that in some cases a total travel of the scene of 5 inches is distributed over 500 frames of film gives an idea of the required refinement of the mechanical devices.

In Act I a sculptured balustrade also is moved across the stage, frame by frame, mechanically controlled in a manner similar to the control of the rollers. The various movements, of course, must be calculated not only for the positions of the planes, but also for their relative speeds with respect to each other. The effect desired is a changing panoramic view as an observer walks along the banks of a river. Various effects, such as a water ripple caused by an unseen fountain, are obtained with especially built effect machines, also operated frame by frame. Some of the figures are modelled in relief upon the acetate sheets. When only a relatively short movement of an element of a scene is desired, the element is painted upon an acetate sheet, mounted upon a "traveller," or frame, fastened to a carriage suspended from an overhead rail. "Universal" frames permit lateral and vertical movements to be made either separately or simultaneously in combination.

The main lighting units consist of three-circuit—red, blue, and white—top and bottom strips. These strips are equipped with Holophane diffusing lenses to provide substantially even illumination upon each plane. The units are so designed and placed that the "spill" between planes is negligible. Each circuit is separately controlled by means of a multi-point rheostat, affording a variation of light intensity from zero to full in increments too small to be perceived by the eye as definite steps. In addition to these main units, separately controlled spotlights, both white and colored, are used whenever necessary. Each light circuit is designated by a number.

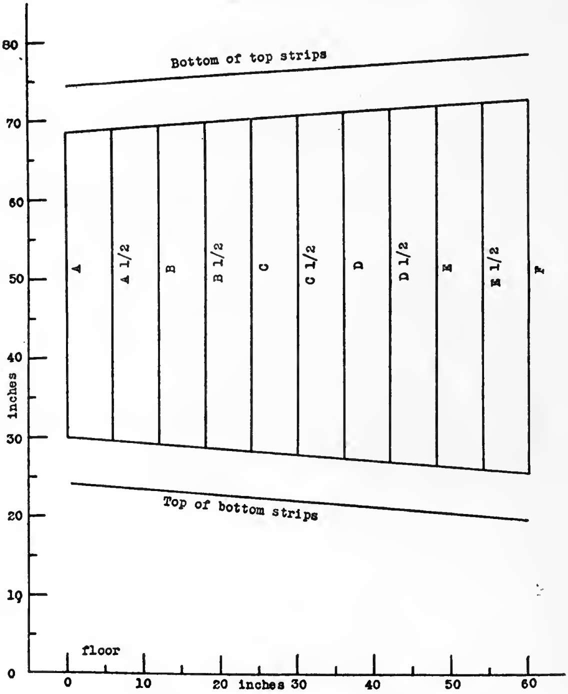

FIG. 2. Dimensions of miniature stage.

The various movements upon the stage, as well as the lights, are manually controlled. A regular routine for the sequence of these movements is established. The average time-interval between exposures during which all movements, light settings, and exposures have to be made, is 12 seconds. With simple action, time-intervals of three seconds between exposures are not uncommon.

The three-color Technicolor process is used to photograph the picture. The exposures are of the order of three seconds per frame. Correct exposure is determined by means of test-strips of the actual scene to be taken. The permissible contrast ratios are also determined by means of these test-strips.

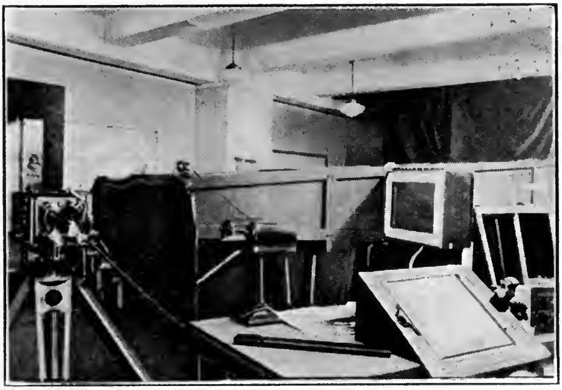

FIG. 3. Arrangement of camera and tunnel leading to plane *A* of stage.

For exposure control, an electrical timing circuit was used during the early part of the work. The time was controlled by a condenser discharge circuit, suitable resistances in which determined the desired time periods. This circuit was arranged to work over a range of $^1/_4$ second to 6 seconds. An Ilex shutter was placed in front of the lens and the camera was equipped with a single-frame advancing device. Through suitable relays operating the shutter release and the camera-tripping device, the exposure and advancement of the film to the next frame became automatic when one control-button was pressed. This control-button was located at the stage, and its operation formed the last link in the chain of operations of scene movements between exposures for each frame.

During the later part of the work, the electrical timing device and Ilex shutter were replaced by a high-ratio reduction gear, and the regular camera shutter was used. However, the automatic control-button operating the stop-motion camera attachment was retained. Fundamental design work indicates that many, if not all, of the movements, as well as the light changes, can be controlled mechanically, thus making it possible to photograph a given scene entirely automatically.

The camera is placed approximately 21 feet in front of the *A* plane shown in Fig. 2. The space between the camera and the *A* plane is totally enclosed in a dull black painted tunnel (Fig. 3). All stage fixtures, as well as the floor and the ceiling, are also painted dull black. Black curtains enclosing the back and stretched across the front of the stage from ceiling to floor, with a light-tight opening fastened about the mouth of the tunnel, are also used. This arrangement permits using the apparatus in the rear of a large room without interference from daylight. It was found that the tunnel between the camera and the stage was important to avoid reflections upon the acetate sheet in the *A* plane. Fig. 3 is a general view of the set-up.

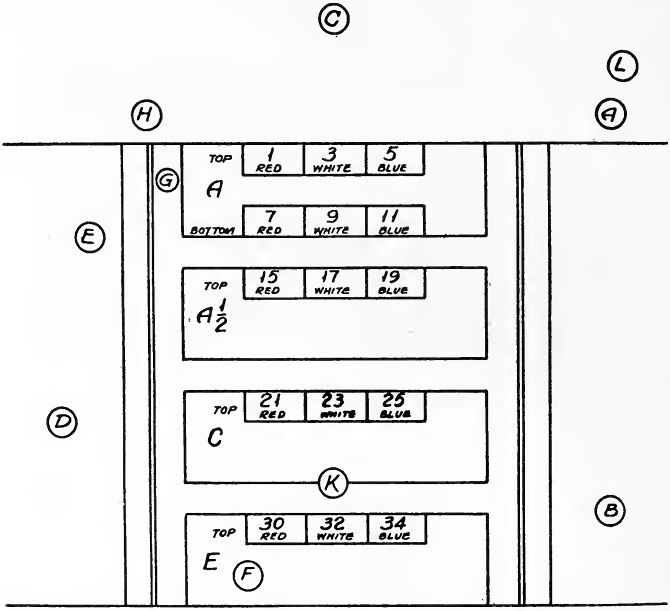

FIG. 4. Light positions; Act I, *Unfinished Symphony.*

It would have been possible to work with much smaller paintings and a much shorter camera distance if only the Technicolor process were contemplated. However, it was desirable for experimental purposes to employ other color processes as well. The focal length of the only lens available for one of these processes, and the fact that the lens could not be stopped down, made the rather large dimensions necessary.

Now to return to the description of the production of the Visual Accompaniment for the *Unfinished Symphony:* It was decided that five acts were necessary to illustrate the composition. An act, in this connection, means a complete change of scenery, requiring entirely new stage settings. The elements available for the production were still paintings, moving paintings, special effects, and light and color changes. From the general layout sheet (Fig. 1) detail layouts are made for each scene. These layouts are timed in seconds and in frames. An action layout covers the stage, and a layout for light changes covers both light-intensity and color changes.

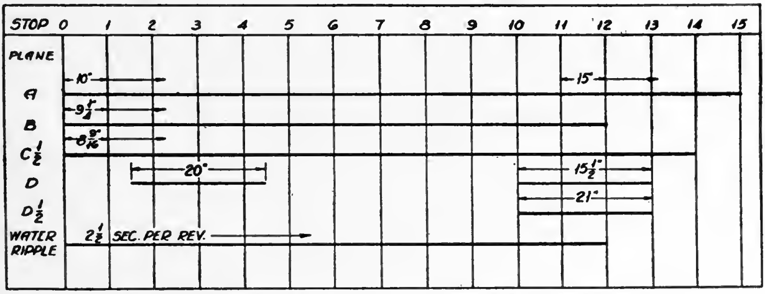

FIG. 5. Action chart; Act I, *Unfinished Symphony.*

As a typical example, consider Act I. This act extended over 122 seconds, or 2928 frames. It called for the following stage settings:

(*1*) Moving clouds in plane *A*, requiring a roller.
(*2*) A sculptured balustrade in plane *B*, mounted upon a movable platform.
(*3*) Painted scenery in plane $C^1/_2$, requiring a roller.
(*4*) Painted effects, such as swan and boats, requiring a "traveler," in plane *D*.
(*5*) Background clouds, moving across the scene and upward, in plane $D^1/_2$, requiring a "universal."
(*6*) A general background in plane *E*, requiring a still frame.

Fig. 4 shows the light layout. The figures and letters refer to the control circuits. The lights required were:

(*1*) Top and bottom strips, plane *A*.
(*2*) Top strip, plane $A^1/_2$.

(*3*) Top strip, plane *C*.

(*4*) Top strip, plane *E*.

(*5*) Spotlight in front of and below plane *A*, shining upon part of plane *A* through an opening in the tunnel.

(*6*) Two spotlights upon stage right, directly in front of plane *A*.

(*7*) Spotlight upon stage left, in front of plane *A*.

(*8*) Small sharp spot, *G*, upon stage left, to illuminate statues upon balustrade.

(*9*) Spotlights upon stage left, shining on plane $A^1/_2$.

(*10*) Spotlight upon stage left, shining on plane *C*.

(*11*) Spotlight upon stage right, shining on plane *E*.

(*12*) Spotlight between planes *C* and *E*, shining upon plane *E*.

(*13*) Effect spot between planes $D^1/_2$ and *E*, to produce effect of water ripple upon plane *E*.

The action and light changes were divided into 15 periods of 192 frames each. Fig. 5 shows the action chart, and Fig. 6 the general light action layout, the figures in which represent the rheostat settings: *24* represents maximal light for the strips, and *48* for the spots.

Fig. 5 indicates that plane *A* is operated throughout the take at a speed of 10 inches for 192 frames up to the beginning of period *11*, and 15 inches for 192 frames from period *11* to the end. A suitable smooth acceleration distributed over period *10* has to be made in this case. Plane *B* (the balustrade) is operated at a speed of $9^1/_4$ inches for 192 frames from the beginning of the action to the end of period *11*, and then stopped, inasmuch as by that time the balustrade is out of the picture. Plane $C^1/_2$ is operated at a speed of $8^9/_{16}$ inches

								MAIN STRIPS													SPOTLIGHTS							
FRAME	STOP	1	3	5	7	9	11	15	17	19	21	23	25	30	32	34	A	B	C	D	E	F	G	H	I	J	K	L
0	0	0	0	24	0	15	24	0	21	0	0	0	8	0	24	24	0	48	0	48	0	33	0	0	-	-	40	0
192	1	0	0	24	0	15	24	0	0	24	0	0	0	0	24	0	0	48	27	48	0	33	0	0	-	-	44	0
384	2	0	10	24	0	20	24	0	20	0	0	24	24	0	24	24	0	48	25	48	0	33	48	0	-	-	40	38
576	3	0	20	24	0	24	24	0	5	0	24	24	24	0	24	24	0	48	25	48	20	33	40	0	-	-	40	38
768	4	24	20	24	0	12	24	0	15	0	24	18	24	0	24	24	0	48	25	48	20	33	23	0	-	-	40	38
960	5	24	24	24	0	12	24	0	0	0	20	13	24	0	24	24	0	48	0	48	20	33	0	0	-	-	40	0
1152	6	24	24	24	0	12	24	0	10	0	20	13	24	0	24	24	0	48	0	48	25	33	0	0	-	-	40	0
1344	7	24	24	24	0	6	24	0	0	24	20	24	24	0	24	24	0	48	0	48	10	33	0	14	-	-	0	0
1536	8	24	24	0	0	6	24	24	3	24	0	24	24	24	0	24	24	48	0	0	20	33	0	19	-	-	0	0
1728	9	24	24	24	0	6	15	24	10	0	24	20	0	0	24	24	48	48	30	48	30	33	0	19	-	-	0	0
1920	10	24	24	24	24	0	15	24	13	0	24	24	0	0	24	24	45	48	48	40	32	33	0	20	-	-	40	0
2112	11	24	24	24	24	0	15	24	24	0	24	24	0	0	24	24	35	48	48	40	32	33	0	0	-	-	48	0
2304	12	24	24	24	24	0	15	24	24	0	24	24	0	0	24	24	22	48	0	40	13	33	0	0	-	-	40	0
2496	13	24	24	24	24	0	15	24	0	24	24	13	0	0	24	24	48	48	0	0	0	33	0	21	-	-	30	0
2688	14	0	4	0	0	18	24	0	3	24	0	0	0	24	18	24	0	30	48	0	0	33	0	17	-	-	25	0
2928	15	0	5	5	5	4	12	0	0	24	0	0	24	0	0	0	0	0	48	0	0	33	0	25	-	-	30	0

FIG. 6. Light Chart; Act I, *Unfinished Symphony*.

for 192 frames to the end of period *13*, and stopped. Plane D is operated a total of 20 inches for 576 frames from period $1^1/_2$ to $4^1/_2$, and stopped, to be operated again $15^1/_2$ inches for 576 frames over periods *10*, *11*, and *12*, and stopped. Plane $D^1/_2$ is operated 21 inches for 576 frames over periods *10*, *11*, and *12*, and stopped. The water ripple is operated at a speed of $2^1/_2$ seconds per revolution (time being screen time) from the beginning of the action to the end of period *11*, and stopped.

Fig. 6 shows the light changes for each 192 frames. Main strip *9*, for instance, does not change from an original setting of 15 for the first 192 frames. From frame 192 to 384 the light increases from 15 to 20; and from frame 384 to 576, from 20 to 24. From frame 576 to 768 it decreases from 24 to 12, and remains at that value to frame 1152. From frame 1152 to frame 1344 the light decreases from 12 to 6, and remains at that value to frame 1728. From frame 1728 to frame 1920 it decreases from 6 to 0, and remains at 0 to frame 2496. From frame 2496 the light increases from 0 to 18. From frame 2688 to 2928 the light decreases from 18 to 4. The last period extends over 240 frames to cover the lap dissolve.

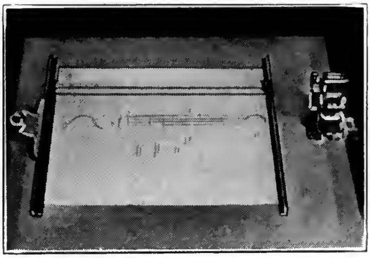

FIG. 7. Control desk and frame counter.

The act was rehearsed by setting significant scenes. The light settings, as well as the positions of the various paintings, were noted. It became, then, a relatively simple matter to work out the light and color transitions between the scenes.

The photographing of a scene is controlled from a desk at which the light action and movement charts are kept. The light changes are read out as they occur. At the desk an electrical counter connected with a push button on the stage is installed to show which frame is being photographed. Fig. 7 shows the desk and counter.

A few figures on the economics of producing the visual accompaniment for Schubert's *Unfinished Symphony* might be appropriate. The personnel required consisted of

2 Artists to make the paintings
1 Camera crew
3 Operators for scene movements and light settings

1 Operator at the control desk
1 General supervisor to coördinate and direct the various activities

In an elapsed time of 325 working hours, 4400 man-hours (not counting the time of the camera crew) were required to complete the production. These man-hours can be broken down as follows:

Operation	Man-Hours
Making sketches	240
Painting	1200
General preparation	590
Rehearsals	1030
Taking the picture	1340
Total	4400.

It is interesting to note that of 208 hours' actual working time spent for taking the picture, only 66$^1/_2$ hours represent shooting time, and 141$^1/_2$ hours were used for setting up and making light adjustments.

Further studies and fundamental design indicate that with complete mechanization of the equipment and reduction in size of the paintings, the schedule would not exceed:

Operation	Man-Hours
Making sketches	240
Painting	600
Rehearsals, *etc.*	250
Taking the picture	10
Total	1100

THE ASTRACT METHOD

The "abstract method" differs considerably from the Savage method, both as to fundamentals and practical realization. The basic thought underlying it is that music suggests color to many persons. The opposite concept, that color suggests music, is also not unknown. It is futile to discuss theories of this method, because there are as many theories as there are commentators on the subject. Instead, a few premises used in the production to be described will be stated:

(*1*) Color is suggested by the "musical mood" of the composition: light colors for gay tunes, and dark colors for somber themes.

(*2*) Color is combined with abstract forms suggestive of the rhythm of the music. Both form and color must be correct from an artistic point of view.

(*3*) Close synchronization of music, form, and color must be established.

In order to produce the visual accompaniment by this method, it is necessary to associate a color-film with previously recorded music. Part of Ponchielli's *Dance of the Hours* was chosen as a suitable composition for this method. Mrs. Josephine M. Wolf, an artist who has made an extensive study of musical themes in color, was chosen to create a set of paintings giving her interpretation of the composition in abstract form and color. The artist required that some of the forms used in the paintings must appear to move in synchronism with the music and also that the intensity of the light must change.

In the picture upon the screen would appear colored forms of abstract shape. These forms change with the music, in shape as well as in color. Through lap-dissolves or wipe-offs, new sets of figures and colors would appear, again to be followed by different designs. When the main theme of the music would repeat, the designs and colors would also repeat, although not necessarily in exactly the same shape or hue. The whole picture would follow the music closely, giving to the audience an impression rather than something definite to follow, thereby further subordinating the picture to the music.

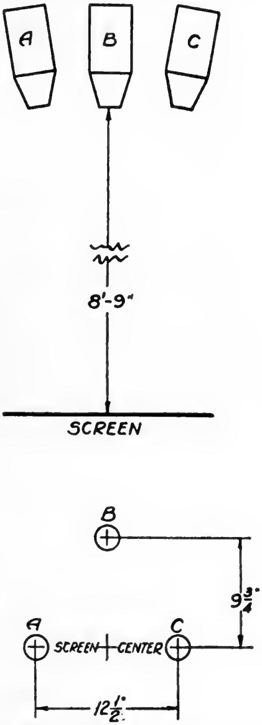

FIG. 8. Projector set-up for *Dance of the Hours;* abstract method.

To furnish the apparent movement of forms, it was decided to make use of a curious phenomenon that had been observed some time ago. If a number of lighted areas of different intensities are projected upon a screen simultaneously from different projectors, and the illumination of one of these areas is changed at a fair rate, the size of the area seems to increase with an increase in intensity and to decrease in size with a decrease in intensity. By using suitable shapes of areas any apparent desired motion can be created. By using different colors for the light areas the apparent motion increases. An illusion of stereoscopic depth can be accomplished by skillful use of this phenomenon.

To carry out the idea, a set-up is made using three spotlights equipped with lantern slide projection attachments and a screen made of flashed opal glass. A sketch showing the set-up is shown in Fig. 8, where A, B, and C denote the projectors. The lantern slides used with these projectors are made as follows: The artist makes the design complete in water colors upon sheets about 8 by 10 inches. These designs are translated into their essential components; that is, a scene consists, for example, of a background, a foreground, and light rays. Fig. 9 shows three such components for a typical scene. The outlines of the components are carefully traced upon a sheet of heavy white paper, and any essential design features are also lightly sketched in. The designs on the paper are cut out, and the separate parts are glued to black cardboard, one to each cardboard. Inasmuch as the designs are cut out of the same paper, there is, of course, no difficulty in maintaining the correct relationship of the parts. The assembled cardboards are numbered and marked in a uniform manner.

These cardboards, with their white paper cut-outs, are photographed. For simplicity, a Leica camera giving a picture 1 by $1^1/_2$ inches upon motion picture film is used. The film used is positive stock, which is developed to as high a contrast as attainable.

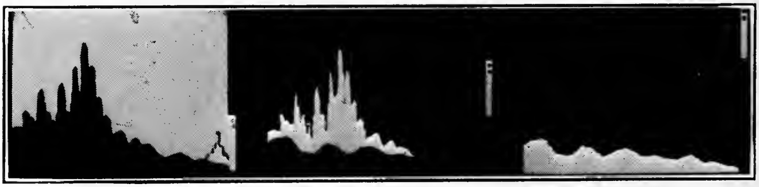

FIG. 9. Components for a typical scene for *Dance of the Hours;* abstract method.

From these negatives lantern slides are made by projection printing. Inasmuch as three projectors are used, the existing parallax has to be taken into account when making the slides. The slides also are developed to maximum contrast, leaving the glass clear at the unexposed portions. They are then hand-colored, using transparent aniline dyes.

The projectors are three Kliegl spotlights equipped with slide carriers and 15-inch projection lenses. The lamps used are 1000-watt, 120-volt spotlights, carefully mounted with mirror reflectors. Means are provided to adjust the positions of the projector lenses slightly to compensate for small irregularities in the slides and the slide carriers. The projection angles are 3°24′ lateral, 5°19′ vertical. The lamps in the projectors are connected through dimmers, permitting a voltage variation of 57 to 118 volts, corresponding to 15 to 140 foot-candles measured at the screen.

Close synchronization of music and picture appeared to be a difficult problem. By using the following method, however, it was solved rather simply: A score of the composition is carefully marked for action and light changes. This score is used as a general guide. A Movieola is set up with a sound-track and a roll of film carrying frame marks, and is operated barely fast enough to permit following the tune. At each predetermined important point a mark is made upon the frame-marked film with grease pencil, and wipes and fades are marked with lines progressing over succeeding frames, the whole action being carefully laid out in this manner. The sound-track and marked film are then run at the correct speed. The film, if correctly marked, will show each important point as it passes by. Corrections, if necessary, are easily made at this time. This film is used to make an action layout directly in frames.

From these data a general layout sheet is compiled, each scene consisting of a separate projector set-up. The action during a scene is controlled entirely by changing the dimmers.

A Technicolor three-color camera is used to photograph the picture projected upon the opal glass screen on the side away from the projectors, running at a speed of one frame per second. No difficulty was experienced in providing the necessary action by dimmer changes at this speed. Stop-motion is used at a few points where the thermal lag of the filaments would not permit the required rapid change for fast action at a constant camera speed of one frame per second.

Further fundamental design work on this method indicates that it will not be necessary to project the picture upon an opal glass screen, nor will colored lantern slides be required. The original drawing made by the artist can be used. This drawing should be made upon heavy water-color paper, with brilliant opaque water colors. The design is again translated into its essential components, and black-and-white lantern slides are made. However, these slides are not colored. The design itself is used as the object to be photographed, illuminated through the slides in the projectors. This method would also permit the use of colored light in the projectors.

The light-intensity should not be controlled with dimmers, but with iris diaphragms mounted at the projectors. In this way the color-temperature of the lamps is not changed, which helps materially in obtaining good color values.

Effect attachments to the projectors, such as rotating color-wheels, flame effects, *etc.*, are too numerous to be mentioned. By using them skillfully, very striking and beautiful effects can be accomplished with the abstract method of visual accompaniment. To date the abstract method has been used only experimentally, and no commercial releases of films made by this method have been made.

Admitting that there is a place for good music in motion picture programs, it is believed that the present-day high-quality reproduction may fill a much-needed want. This is particularly true if an artistic visual accompaniment to the music is provided upon the screen. It is therefore expected that this new art combining fine music faithfully reproduced and "Visual Accompaniment" will fill a gap in the amusement field and provide for the audiences of motion picture theaters a very worth-while supplemental form of entertainment.

Several demonstration films illustrating two of the forms of visual accompaniment were projected after the presentation of the paper as follows: Musical Moods—"*Fingal's Cave*" (*Mendelsohn*), "*Italian Caprice*" (*Tschaikowsky*), "*Barcarole*" *from* "*Tales of Hoffman*" (*Offenbach*); Savage Method—"*Unfinished Symphony*" (*Schubert*), "*Les Preludes*" (*Liszt*).

THE USE OF FILMS IN THE U. S. ARMY*

M. E. GILLETTE**

***Summary.**—An outline of the use and production of educational motion pictures in the United States Army, together with a discussion of their use in conjunction with the "Applicatory Method" of instruction.*

The Army's interest in motion pictures began shortly before the World War when the Medical Corps produced and experimented with the use of pictures on social hygiene and other medical subjects. As is well known, the Signal Corps made hundreds of thousands of feet of film during the World War in visually recording important events and activities. This material, together with subsequent additions, probably constitutes the largest and most valuable collection of historical pictures in the government service. Entertainment pictures were widely used during the War by welfare agencies within the Army. Since the War, the Army Motion Picture Service, directed by the Adjutant General's Department, took over this work and now operates a chain of post theaters in which feature pictures, obtained through regular booking channels, are regularly shown. This is an important activity contributing to the contentment and high morale of service personnel, especially in the more isolated stations.

It is not so well known, however, that the Army was one of the pioneers in the use of motion pictures upon a large scale for educational purposes. In addition to the Medical Corps films just mentioned, sixty-three reels of military training-films were produced by the Signal Corps during the War; and many other reels, such as the animated *Elements of the Automobile,* were made by commercial agencies specifically for military uses. The production program was in full swing at the time the armistice was signed in November, 1918, with more than a hundred reels of pictures on military training subjects in use.

The value of this material as a training adjunct was recognized;

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** U. S. Army, Washington, D. C.

but immediately following the World War the pressure for readjustment in the service stopped all new production and precluded further extensive experimentation, although the war-time subjects continued in circulation. No new subjects were produced until about 1928, when a renewed interest in visual education brought about the adoption of a definite program of production and the establishment of rules governing the initiation and conduct of training-film production projects. The Signal Corps was designated as the agency charged with technical production matters, with the various branches of the service collaborating in determining picture content and scope.

In 1930, the Signal Corps acquired a sound recording channel, and through the coöperation of the motion picture industry, arranged for training, over a period of years, a few selected officers in sound motion picture production methods. Three officers have received this training to date, the first completing the course in June, 1931. In 1931 and 1932 a few silent films were revised and off-stage monolog was added to make the films more effective. Since then additional sound subjects, both natural sound and the monolog types, have been undertaken. A total of twelve sound training-films have been released, and seven additional subjects are now in various stages of production.

A brief examination of the main steps in the course of a training-film project may be of interest. The chief of a branch of service, such as the Chief of Infantry, Chief of Cavalry, *etc.*, decides that a training film upon a certain subject should be produced. Application is made to the War Department for approval of the project. Approval granted, the Chief designates an officer, usually a specialist in the subject to be covered, to prepare the scenario and act as technical director for the picture. The completed scenario is submitted to the War Department and referred to the Chief Signal Officer for comments regarding feasibility of production from a photographic and technical standpoint and for recommendations as to its position in the production schedule. These preliminaries completed, details are then worked out as to the place and dates for performing the field photography. The Army has no production stage facilities but must rely upon suitable terrain or other background requirements available at one or more of its numerous stations. Film processing, animation, editorial, and similar tasks are carried on at the Signal Corps Photographic Laboratory at Washington, D. C.

The field production unit consists of the director, designated by the Chief Signal Officer, cameramen, recordist, and other assistants from the Signal Corps Photographic Laboratory. The officer who prepared the original script is usually designated to act as technical director or advisor besides acting as liaison officer in arranging for the use of troops, equipment, and so forth. Leading characters and troops are supplied by the interested branch.

Upon completion of the field photography, editorial and related work is carried on at the Signal Corps Photographic Laboratory until the picture is ready for presentation to representatives of the interested branch and to the Plans and Training Division of the War Department. Upon approval, release prints are made and distributed to the nine Corps Area Headquarters, the three foreign departments, the service schools, *etc.*, so that distribution of prints for exhibition purposes is decentralized. Several additional prints are retained at Washington to meet additional demands. The Signal Corps makes use of commercial equipment exclusively, and the production and processing methods are copied, as closely as the limited funds and personnel will permit, from similar processes or methods in general use in the motion picture industry.

The term "educational motion pictures," is frequently used within the Army, as elsewhere, to refer to general interest, propaganda, travelog, and record types of pictures, as well as to instructional films. One hears occasional references even to entertainment pictures in this category. Such a meaning is regarded too broad and vague for Army purposes. It is desirable to limit the term to pictures produced specifically for instructional purposes, which pictures will hereafter be referred to as training-films. The remarks that follow are restricted to a discussion of methods of presentation and the production technic applicable to military training-films, which, because of their general nature, may be of interest to others interested in the production of instructional films.

According to service manuals, the ultimate purpose of all military training is effectiveness in war, with a view to maintaining the domestic peace and international security of our people. It follows therefore, that training-films must contribute effectively to this objective. Interest is therefore restricted to subjects having direct military value, and such high specialization makes it necessary that military personnel perform the directorial and editorial phases of the work.

The Army's training methods are based upon the applicatory system of instruction, in which individuals or organizations under instruction are required to apply the principles or methods to an assumed or outlined situation. There are six steps or phases of this system:

(*1*) Preparation on the part of the instructor.
(*2*) Explanation.
(*3*) Demonstration or illustration.
(*4*) Application or practice, to acquire skill in execution.
(*5*) Examination or test, to determine progress or proficiency.
(*6*) Discussion, to correct methods of execution.

There are no "royal roads to learning" or "get-rich-quick shortcuts" in this educational system which, in the majority of cases, requires physical as well as mental exertion by the soldier to attain proficiency in military subjects. Obviously, training-films can not be used as the only means of instruction in the system but must be fitted, as a part, into the educational method. Their role must be that of an *aid* or *tool* in the hands of an instructor, and never that of a teaching robot usurping all the functions of the instructor, as extreme enthusiasts may sometimes contend. Our training-films, designed for use as aids in one or more of the steps listed above, can be made to shorten the explanations or demonstration phases materially, as well as to afford more vivid and compelling presentations than would be possible by other means.

It must be borne in mind, however, that all subjects are not equally suitable for motion picture treatment. On the other hand, many subjects lend themselves admirably to such purposes, and are more effective in motion pictures than in any other form. In general, it is regarded desirable to restrict subjects selected for motion picture treatment to technical subjects and technic in which there is but one set of facts or one correct method of performance. Functioning and nomenclature of weapons and equipment fall into the first group, while pictures showing approved methods of employing weapons, of drilling and other exercises, fall into the second classification. Controversial subjects or those susceptible of solution by more than one applicatory method are regarded as less suitable because of the difficulties of presentation and the danger of imparting the impression that there is but one approved solution. Let us now ascertain just where training-films can fit into the applicatory system.

(*1*) The first step is *preparation on the part of the instructor* for his duties. Military instructors are usually selected because of their proficiency or experience in certain subjects. They have access to military texts, manuals, and regulations with which to refresh their memories and otherwise prepare themselves for the class period. These publications contain a mass of detailed information which it is impracticable to cover thoroughly in pictures. Training-films are of little value in preparing the peace-time instructor for his duties but in war-time when thoroughly trained instructors are scarce, pictures will undoubtedly become of more value in the first step.

(2) *Explanation* consists of a word-picture presented in the expository manner, by the instructor. Step by step he goes over the lesson, utilizing equipment or personnel in many cases to keep the class oriented and aid in his verbal presentation. The use of a recorded lecture for this purpose is physically possible but is not an efficient means, for various reasons. When used in conjunction with pictures or illustrations, the explanatory phase tends to become combined with the demonstration phase. The off-stage voice or monolog is a very efficient means of presenting a standardized explanation and is readily correlated with diagrammatic or illustrative material to make the presentation more effective. It is possible to design pictures specifically for this phase but it is frequently difficult to determine whether a picture belongs in this phase or in the demonstration phase, due to a close intermixture of the two, as will be discussed later.

(3) *Demonstration, or illustration,* may consist in a demonstration by the instructor or by a selected group of highly trained persons, or in the operation of equipment or weapons by selected personnel. In many cases, the instructor will restate portions of his original explanation as the demonstration progresses, in order to stress or drive home the important points. Sound motion pictures are probably of greatest value in this phase. They permit the use of a standard comment coupled with a silent picture demonstration, the use of a complete natural-sound demonstration, or a combination of the two as best fits the subject at hand. Such pictures provide means for visually demonstrating operations to large groups where lack of facilities or the nature of the demonstration prohibits the class from seeing an actual demonstration. Many operations are difficult to perform without incurring danger for the personnel or consuming expensive supplies.

As has been indicated, the question frequently arises as to whether a certain picture should be used with the second step, *explanation,* or with the third step, *demonstration.* Special pictures utilizing monolog may be used in the explanatory step, while separate pictures using natural sound or monolog may be used for the demonstration. A common practice is to combine the two in the same reel or reels. One method is to explain the lesson, step by step throughout its entire length, and then follow with natural sound, a monolog, or a silent picture demonstration. Another practice is to explain an individual point with diagrams, and follow immediately with a demonstration covering the particular point. It is usually desirable to finish off the picture with a complete demonstration, as a whole, of all points covered. Other variations may be used without violating the basic principles of the applicatory system. Standardization of explanation and demonstration can be attained in this manner in a minimum number of reels.

(*4*) In the fourth step, *imitation or application* on the part of the student, motion pictures are of no value. This step requires mental and physical effort in most cases for the student to acquire proficiency. During this phase it will often prove desirable to review the demonstration picture several times to permit closer examination of troublesome portions of the subject. This device brings this step into intimate relationship with the next two steps.

(*5*) In the fifth step, *examination,* sound motion pictures will frequently aid by providing a visual yardstick or standard against which the soldier's or the unit's proficiency may be measured. Pictures designed for use as aids in the third step will normally serve this purpose. It is not believed that special pictures designed for use only in this phase are justified.

(*6*) The sixth and last step is the *discussion to point out correct and incorrect methods of execution.* Pictures designed for use in the third step, *demonstration,* must always show the correct method of execution. Great care should be used to be sure that the students obtain a clear visual concept of the correct method. Inclusion in the third step of demonstrations showing incorrect methods generally tends to confuse the pupil and befog the salient points. For these reasons a picture designed for use in the third phase is not entirely suitable for use as an aid in the last phase. If motion pictures are to be used effectively in this phase, they should be specifically planned for the purpose. Such pictures can unquestionably be made of considerable value, but are regarded as subordinate to those designed for the third phase. Their production is not justified so long as we have not exhausted the possibilities of making demonstration and explanatory pictures showing correct execution.

According to the best pedagogical practice, a course of instruction upon a subject is broken down into a series of lessons or lectures, each of which deals with a few important points. Not more than one lesson per day is the normal rule, and several days or weeks may be required to cover a subject completely. In the military service, where pressure for time is frequently urgent, two periods per day per subject may be utilized. The limiting factors in this respect are the powers of assimilation exhibited by the students in a given period of time. The assimilation can be improved considerably by the use of visual aids but it is unreasonable to expect that all such limitations can be overcome so that a subject can be taught in a single showing.

It is advisable to plan training-films in parts or sections to fit the various lessons of a course of instruction. It is also necessary to realign the courses of instruction to make the most efficient use of the training-films. While it is not feasible or desirable to have separate parts or reels for use with every separate lesson, it is desirable to fit such pictures into the course where their use will be superior to other methods of instruction. Several lessons may be consolidated into one part, for use in visual and aural summarization; or each part may be designed to demonstrate and explain some abstract or difficult point and otherwise aid in putting across a single lesson. Properly used as visual aids, training-films should materially reduce the number and length of the lesson periods necessary to master a subject. The extent to which these can be reduced by the use of training-films is a direct measure of the value of such aids.

In the Army, as elsewhere, the high costs of production and the limited facilities for production have tempted us to cram a complete course of instruction into one film, of, perhaps, five or six reels, designed for showing in a single session. In some cases only the high points have been covered, leaving the details for presentation by other methods. In other instances an attempt has been made to cover all the details; which has resulted in creating confusion in the minds of the pupils because of the rapidity and number of points presented in a short time. This type of picture may handicap rather than help the student. The better method is believed to be that in which the subject is broken down into sections or parts, each of which contains sufficient detail presented in such a manner as to enable the student to master each step successively. The number of major points presented in a single session should not overtax the mental ability of the class. Moreover, the pictures should cover only the work immediately before the student; otherwise, extraneous or advanced material would distract the thoughts and thereby tend to defeat the purpose of the lesson.

This brings us to another major point. Training films must be designed for use in training a particular group. Obviously, pictures planned for audiences of officers will generally be beyond the comprehension of average enlisted men. Conversely, those designed for enlisted men will frequently appear dull and uninteresting to officer classes. The technic of presentation must be varied to suit the mental age or capacity of the class at which it is aimed.

While the silent picture has considerable value as an instructional aid, depending entirely upon vision to convey its message, it is inferior to the natural sound, the off-stage voice, or the monolog pictures, which reach the student through both the aural and visual senses. The use of off-stage or monolog sound—"the voice that knows all, sees all, tells all"—is effective as a means of standardizing the explanation, and in general will permit the presentation of a greater number of points in a given length of time than is possible in a natural-sound picture. Natural-sound pictures provide the best means of reproducing a scene in all its details of sound and action. Whether natural sound or the off-stage voice is to be used depends upon the nature of the sound and whether such sound or monolog can be made to stress the desired points effectively, clearly, and directly. In many, if not the majority, of subjects, a combination of the off-stage voice and the natural sound will prove most effective. Monolog in such films is effectively used to pass over unimportant details rapidly, to link together or explain the significance of an event, or to prepare the audience for scenes to come. It can be used also to summarize or stress the lesson points. In this mixed type of picture care must be exercised to keep the audience oriented as to who is speaking. A distinctive off-stage voice coupled with suitable pauses and intonations following or preceding natural-sound sequences is usually effective in this respect. In general, the interspersion of short natural-sound and monolog sequences is objectionable, resulting in choppy and confusing presentation. Natural-sound sequences containing no significant dialog may be used in some cases as background for the off-stage voice, but they must be subdued and made subordinate so that they will not mar the intelligibility of the presentation or distract the attention of the class. Properly handled, this often proves the most effective method of illustrating certain classes of material.

The use of animated drawings is one of the most effective means of illustrating certain kinds of material. Functional processes of equipment and weapons can be demonstrated in this manner. For example, a complete picture of what occurs in the recoil mechanism of a big gun can be visually demonstrated by no other method. In making our animated pictures, several different methods are used. Articulated cut-outs, miniatures, pointers, moving arrows, and regular cut-outs as well as drawings and erasure before the camera, are some of the devices used in addition to the familiar celluloid overlay system. The method chosen depends upon its adaptability and economy of execution in presenting the desired point. Miniatures, projection backgrounds, and similar devices of the special-effects stage could be effectively used in many cases to produce results attainable in no other way or as inexpensively.

Many of the cutting tricks used successfully in producing entertainment films can not be employed in instructional films. For example, as little as possible should be left to the imagination of the student. The presentation should be in the expository manner, so that the observer is led step by step through the various processes. Emotional or spectacular scenes are highly undesirable, and must be avoided except when their use illustrates the point in question. Many of the little tricks used with success in building a story up to a climax may also be employed in training-films. Repetition of sound or scene, change of viewpoint, and the tricks of going into intimate details can be used effectively.

The use of humor is a questionable point because it usually serves to divert attention. It is frequently found, however, that many operations or actions performed in a serious manner will provoke laughter from the audience. This is particularly true when the actor makes some slight error or appears awkward or self-conscious in his role. Continued repetition of a slight idiosyncrasy on the part of an actor, or some unusual action or view of equipment in the scene also may provoke mirth and thereby destroy the effectiveness of the picture. Unrelated picture or sound action, such as trains moving in the background, twittering of birds, and the like may prove more distracting in the picture than if the class were actually present at the scene of action. Great care must be exercised, therefore, to eliminate these and any other picture or sound diversions. Theoretically this can be accomplished by restricting the scene and sound content to the actual instructional requirements, but in practice this is frequently difficult to accomplish because the scene and camera locations must always be practical.

All the various camera, optical printer, and sound tricks can be called upon to assist in improving the effectiveness of the training-film. Zoom shots from long views to close-ups and the opposite are effective in maintaining orientation and at the same time provide opportunities for examining minute details. Follow-up shots can often be used effectively to follow an individual or an operation through a complicated situation. Slow motion can be used to examine operations normally occurring at speeds too fast for visual analysis. Stop motion will provide opportunities for examining details at any point of the action, and time-lapse photography can be used to speed up processes occurring too slowly for the eye to evaluate. The microscope and telephoto lenses can be used to examine minute or distant objects, and animation can give life to abstract theories and inanimate bodies. Cross-cutting of pictures with animated drawings, used freely in training-films, is seldom found in combined form in the entertainment field. Cameras operated by remote control can afford intimate scenes of events in dangerous spots. Cameras placed at strategic points provide means for reproducing an event or series of events occurring over a large area, or at widely separated points, in a closely integrated and correlated form. The use of split-screen technic is suggested as one means of showing two widely separated operations simultaneously. We can reach back into time through film libraries and bring back events long past, to illustrate our lessons. The World War files are especially valuable in this respect. Superimposed titles, moving arrows, travelling mats, and similar devices of the optical printer are effective in focusing attention upon a particular part and in suppressing unimportant details. Sound amplification makes it possible to hear sounds of low intensity and provides a ready means for giving large classes intimate details of such things as orders received over telephones, whispered commands, and distant noises. All these and many more tricks of the motion picture art are available, and should be used where applicable by the serious producer of instructional films.

MOTION PICTURES IN THE ARMY AIR CORPS*

G. W. GODDARD**

***Summary.**—An outline of the extensive aerial motion picture activity now being carried out in the departments of the Army Air Corps. The relation between the various Air Corps units is explained, and the many uses to which motion pictures are put in instruction and training, technical studies, maintenance and inspection of aircraft, etc., are described.*

Slow-motion pictures have proved very valuable for investigating the causes and progress of fire in airplanes, the operation of parachutes, the effectiveness of demolition of bombing, etc. Lectures recorded with the pictures explain the operations of blind flying, loading bombing racks, releasing bombs, and the like. Motion pictures of vast territories are taken quickly by planes flying en masse.

The Wright Brothers successfully completed the first heavier-than-air flight at Kittyhawk, N. C., in 1908. Motion picture photography has played an increasingly important part in the development of aviation since that date. Largely through the medium of the screen, the people of the world have followed its progress and have been educated to its tremendous possibilities. Prior to the World War most of the motion picture films of aviation developments and activities were made by the newsreel companies, and all of these films have been preserved as historical records for future generations. As far as known, there was no other application of the motion picture art in aviation until the armies engaged in the World War adopted the motion picture camera gun, which solved the problem of training military aviators in aerial gunnery and combat without expending valuable ammunition and subjecting the personnel to the hazards of such training.

The first camera gun was equipped with the standard automatic motion picture mechanism, a film magazine which was readily replaced during flight, and an extremely long focal length lens to produce a large image of the target airplane upon the film. The camera

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was equipped also with a time-recording attachment which recorded the time upon the edge of each individual frame of the film; and thus with celluloid film the student was allowed to view his results in the negative. The complete unit was mounted upon a standard Lewis machine gun. Later this was replaced with a paper film which could be redeveloped into a positive and easily handled and viewed by the student gunners. The complete unit was mounted upon a gun tourelle in the gunners' cockpits of bombing and observation airplanes. This wartime camera gun was not adapted for use in single-seat airplanes because of the difficulty of mounting it. Several thousand camera guns of this type were in use in the Army Air Service at the close of the War, and hundreds of Air Service photographic specialists were assigned to their maintenance and to the laboratory details of film developing and finishing.

Following the introduction of the camera gun, the Army Air Corps readily recognized the importance of producing, with the Air Service personnel, historical, publicity, and training motion picture films accurately depicting and permanently recording the rapid development of military aeronautics in all its many departments. In furtherance of this plan, all Army Air Service photographic sections were equipped with Universal motion picture cameras of 200-ft. capacity and special mounts for ground and aircraft use.

During the years following the war, the early type of gun camera has been superseded with the development and adoption of the type *G-4* camera gun, which has greatly increased the efficiency of aerial gunnery. With this modern camera gun, a series of pictures is taken of the target, recording the aim of the gunner and stop-watch timing the aim at the instant of firing. The shape and size, as well as the weight, of the *G-4* motion picture camera have been made as nearly as possible mechanically to resemble the Browning 0.30 caliber machine gun fitted for flexible use, so that the operator of the camera gun may transfer easily and naturally to the machine gun and use the latter with deadly accuracy as a result of his motion picture camera gun training.

The principal difference between the two assemblies is the absence of recoil when using the camera. The *G-4* motion picture gun camera takes pictures at the rate of approximately 16 frames per second. Each picture represents a shot fired, and records the aim by means of cross-lines in the optical system which coincide with the cross-wires of the gun sight. In addition, the instant of each camera shot is recorded upon each picture by synchronizing a stop-watch with the motion picture camera gun shutter.

The *G-4* camera may be used for both fixed and flexible gunnery training purposes during offensive and defensive maneuvers. The record of scoring hits may be studied individually or in burst groups, by an individual or in classroom instruction, thereby providing graphic means for correcting previous errors. Registering the stop-watch timing of the shots makes it possible to conduct training programs, including aerial combat between two or more airplanes equipped with motion picture camera guns, and record the time of the first as well as the time of all vital shots fired.

In addition to providing for training the personnel of observation and bombardment airplanes, provisions have been made for mounting the camera in the top-wing section of single-seat airplanes for training pursuit personnel.

The *G-4* camera is actually a ruggedly constructed motion picture camera with its components so arranged as to fit into a framework or housing resembling that of an aircraft gun and designed to permit installation upon a flexible gun-mount by means of a special adapter assembly. The film used is of the standard 35-mm. motion picture type; it is 35 feet long, has a leader of 5 feet, a sensitized film of 25 feet for exposures, and trailer of 5 feet. The film is loaded in the camera through a door hinged to the right side of the gun camera body assembly, and an electrical type of film indicator, for either direct or remote installation, is provided to show the operator, by flashing light signals, that the camera is operating, and by continuous light, that the film has been exhausted. The leader and trailer ends of the film are of insensitive material and allow the camera to be loaded in the daylight. The film proper provides approximately 250 exposures, which are taken automatically as the camera trigger is released at approximately 16 exposures per second. The time-registering device optically projects a photographic image of a stop-watch dial and full-sweep seconds hand upon the film below the main image, and thus records the exact time at which each exposure is taken. This type of camera is being used also by the aviation sections of the Navy and Marine Corps.

Preceding, and coincidentally with, the development of the motion picture camera gun came the development and use of aerial motion picture cameras. Needless to say, the first motion picture cameras used in aerial work were of the ordinary tripod hand-cranked military aviation, not only in the Army Air Corps but in the Naval Aeronautics Branch and the National Advisory Committee laboratories at Langley Field, Hampton, Va. It is fully recognized that the cost involved has been very small considering the results obtained.

The Army Air Corps maintains still another aerial photographic and motion picture activity. This is the photographic School of the Army Air Corps Technical School, located at Chanute Field, Rantoul, Ill. At this school are trained the Air Corps Photographic officers and enlisted men, and all the many skilled technicians required for taking, developing, printing, cutting, and editing all types of aerial motion picture films. All Army Air Corps motion pictures, other than the engineering and technical films and films produced locally by the photographic section, are taken and produced by the Photographic School of the Air Corps Technical School in its complete laboratory, which is a department of the Aerial Photographic School. This motion picture laboratory is maintained for the purpose of training officer and enlisted photographic personnel, as well as for general production work of the Air Corps. Expert motion picture personnel from this school is assigned to all major projects of the Air Corps, where the films to be taken are not of direct value to the Materiel Division.

Sound camera equipment has been specially constructed for the Air Corps for the production of Air Corps motion pictures. The weight of such equipment has been materially reduced and the equipment itself is transported to the various locations in special school photographic transport airplanes. The pilot and mechanics on such missions perform the roles of director, cameraman, and sound technician. Adjacent to the Photographic School at the Air Corps Technical School is located the Communications School, which coöperates with the Photographic School in furnishing the required radio technicians, as needed, for the operation and maintenance of the sound recording equipment. In January, 1934, complete sound camera equipment was flown to Rockwell Field, Calif., and Air Corps flying personnel completed a four-reel sound motion picture covering the Army Air Corps School of Aviation activities. Approximately 70 per cent of this film was completed in the air, showing the duties of the personnel engaged in fog flying, commonly known as "blind" flying, and the latest methods of aerial navigation. The film was completed for the historical record of the Army Air Corps, and has since proved to be very valuable for instructional purposes in Air Corps schools, National Guard, and Air Corps Reserve Units. Last spring this film served a very useful purpose in connection with the aerial training of West Point cadets as recommended in the findings of the Baker Board, appointed by President Roosevelt. Included in the present schedule of motion picture work is the project of the Photographic Department of the Air Corps Technical School to assemble and edit the 4000-ft. sound-film entitled *Wings for West Point.* This film was photographed last June at Mitchel Field, Long Island, and shows the extent of aerial military training given to the second-class men at West Point. This historic film follows the student through all his training, from his arrival at Mitchel Field to his departure therefrom. Approximately 70 per cent of the film was taken in the air, showing the cadets carrying out the various navigation and aerial gunnery missions. The ground sequences of the film show in detail the cadets inspecting the various types of tactical airplanes and equipment, and also the routine ground training during the training period. The scenario for the film was prepared by photographic personnel at the Army Air Corps Technical School and the dialog was written by an Air Corps officer on the Commanding Officer's staff at Mitchel Field, who was thoroughly familiar with West Point training details. The modern air-conditioned photographic laboratory facilities of the Eighth and Fourteenth photographic sections at Mitchel Field were made available for the photographers so that immediately after each scene was photographed test developments could be accomplished. The assembly details of the West Point film are being accomplished in connection with the routine training of student photographers, as well as are those features pertaining to chemical mixing, developing, printing, editing, drying operations, and projection. In addition to this work, the present photographic school schedule includes the preparation of a bombing film for instructional purposes at the Air Corps Tactical School, Montgomery, Ala. Approximately 90 per cent of the film will include Air Corps bombing scenes now in the files of the Engineering Division and the Film Library, Office, Chief of Air Corps. The necessary new sequences will be completed by expert trained aerial cinematographers at the various Air Corps photographic sections assigned to tactical units concerned. It is expected that approximately 95 per cent of the film will consist of air scenes depicting all types and conditions of aerial bombardment, and will prove of great training value to the Tactical School and to tactical line units, the National Guard, and the Reserve Corps. One of the features of the picture will be the Engineer-military aviation, not only in the Army Air Corps but in the Naval Aeronautics Branch and the National Advisory Committee laboratories at Langley Field, Hampton, Va. It is fully recognized that the cost involved has been very small considering the results obtained.

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Occasionally, specialized personnel, and with airplanes of the modern service type, are ordered to the Air Corps Technical School from the tactical units and other service schools to give lectures and demonstrations to the school departments. By order of the Commanding Officer, all lectures and demonstrations of this nature will be recorded and photographed by the Photographic Department and made available for future instruction. Recently a new type of attack plane was flown to Chanute Field and a motion picture film was made showing all the details of a lecture given on it, including the loading of ordinary bombs and parachute bombs upon the latest type of bomb racks. The films showed also the method of release, and the actual release, of the bombs during flight. The complete lectures, which were given by an Ordnance Officer from Shreveport, La., were taken in shorthand and are available for completion of the sound details of the film, which it is expected will be incorporated in the bombing film being made for the Tactical School. These examples are only a few of the many that demonstrate the practicability and the need of maintaining a modern motion picture laboratory at the Army Air Corps Technical School.

Other films completed to date by the Army Air Corps Technical School include the film made on the flight to and from Alaska and during the operations at Fairbanks, when Army Air Corps photographic planes demonstrated the practicability of mass photographic flying and photographed 35,000 square miles in seven hours and forty-five minutes of actual time of photographing. Aerial motion picture personnel of the school also accompanied the Army Air Corps Cold Weather Test Flight along the Northern border in 1934 and photographed the operations of the flight. These films have been turned over to the Engineering Division and have assisted that activity in the further development of arctic weather flying equipment.

Civilian instructors, under the supervision of the Director of the Department of Mechanics, which department conducts the training of all Air Corps mechanics, are now preparing a dialog for a local training film covering the standard procedure of maintaining and inspecting Army aircraft. The work is being accomplished along with the routine work of the school, and the photographing will be done by the Department of Photography during regular instruction of the classes.

As previously stated, there are fourteen photographic sections of the Army Air Corps. These are located in the nine Corps Areas in the United States and in three foreign possessions. The purpose is to complete in the most economical manner all photographic training missions and miscellaneous aerial surveys for the respective Corps Area headquarters. Each aerial photographic section is composed of twenty enlisted photographers and technicians under the command of a photographic flying officer. Most of these photo section laboratories are quite modern and include air-conditioning, temperature-control, and dustproof equipment. They have been constructed within the past two or three years in connection with the general building program of new Air Corps stations. Each laboratory is equipped with motion picture developing equipment and cameras adaptable for use in all service type airplanes and upon the ground. The operators of the equipment are thoroughly experienced in both the operation of the camera and the use of the laboratory equipment. These technicians are thoroughly familiar with local atmospheric conditions as they affect aerial and ground cinematography. The present arrangement of locating cinematographers in all the Air Corps photographic sections is regarded as very efficient in that all special happenings in that vicinity are immediately photographed and the developed films rushed to the Chief of the Air Corps for distribution to the newsreels and for the permanent library of the Chief of Air Corps. In order to keep the personnel in proper training, each section is required periodically to test its equipment in the air and to mail the films to Washington, where they are closely inspected. A fresh stock of film is carried in the supply depots of the Air Corps and is available to the sections upon requisition. Most of the film is furnished in 200-ft. lengths for use in the standard aerial motion picture cameras, which are equipped with 200-ft. magazines.

Panchromatic No. *2* is the type of motion picture negative film generally used for aerial motion picture photography in the Army Air Corps. For years it has been found that Panchromatic No. *2* produced best results when used with the standard Air Corps filters employed in making still aerial photographs. Although this film is comparatively slow-speed, it is sufficiently fast to permit the use of the *K-3*, minus blue, and *A-25* filters. On clear days, between the hours of 8 A.M. and 4 P.M., when filters of the minus blue and *A-25* types are used, the lens opening is set at *f*/4.5, infinity focus, 180-degree shutter opening, and the photographing done at 32 frames per second. The type of filter and the lens opening vary, depending upon the atmospheric conditions in certain sections of the country. When using Panchromatic No. *2* for low-altitude pictures taken over cities or along the coast line where there is a marked degree of contrast, filters of the *Aero One* type are generally used, and the stop is reduced to *f*/8, at 32 frames per second. When producing aerial motion pictures of this type the primary interest lies in detail rather than in pictorial effect; hence the need for the finest possible grain. Our experience has been that this is obtained to the best advantage in Panchromatic No. *2* film. The use of supersensitive motion picture film is resorted to only for early morning or late evening missions, or under bad weather conditions, when the light is extremely poor.

A most difficult problem is presented in photographing Army Air Corps formations or single airplanes, in that the present colors of the airplane cover the two extremes of contrast, the wings being painted bright yellow with an enamel finish, giving a high reflection factor, and the fuselage being painted a dark green, usually without an enamel surface, and having a low reflection factor. In this case it is necessary to photograph the formation or single airplane, and sacrifice the results in the distant landscape. The Army Air Corps recently issued an order to all repair depots to change the green color of the fuselage to a light blue. This will be very helpful in photographing airplane formations in the future. Another difficulty encountered in photographing the latest types of airplanes has been occasioned by the increased speeds of the new types of military aircraft, compared with the speed of the present type photographic airplanes. In photographing single airplanes or formations in flight, it is very necessary that the photographic airplane be able to outdistance the airplane being photographed in order to move into position for satisfactory pictorial composition. In recent months it has been necessary to arrange camera installations in non-photographic airplanes in order to correct this condition. It has been extremely difficult to make satisfactory camera installations, as it generally happens that the desirable positions are occupied by other pieces of necessary equipment. When the 200-miles-per-hour Martin bombers were flown over Alaska it was necessary to install the motion picture camera equipment in the front cockpit of a bomber and cut a hole through the celluloid turret cowling protecting the forward gunner. A set-up of this kind was used exclusively for motion picture work on the Alaskan flight. The oval celluloid enclosure with the camera mounting attached provided full swing of the camera and mount to any desired position. The location of the camera in the nose of the airplane in this instance proved very desirable in that it was away from the motors and kept free from oil, which generally accumulates upon the lens when the camera is mounted at the rear of the motors. The camera operator on the Alaskan flight was provided with a radiophone so that it was possible for him to talk to the pilots of the planes being photographed and give them necessary instructions as to the desired formation.

Considerable difficulty is experienced in the operation of cameras in cold weather, particularly on planes flying at high altitudes where the camera is exposed to the wind blast. Constant attention to the proper lubrication of the moving parts is necessary. Moreover, as previously indicated, the operator must be constantly on the alert to prevent oil from covering the lenses, particularly in single-motored airplanes, in which the camera is mounted directly behind the radial motors which throw off a fine spray of oil from the cylinder heads and accessories.

In connection with the maintenance and repair of aerial cameras and other equipment, including laboratory equipment, most of this is attended to in the units and activities concerned. However, major repairs are completed either at the factory producing the equipment or at the Materiel Division. Army Air Corps motion picture cameras in most cases are operated electrically from the 12-volt airplane power supply.

Aside from the historical, publicity, and training sound motion pictures required by the Air Corps, it is believed that motion picture photography will play a very important part in future military observation operations. The speed of the military airplane now being developed will be much too high to permit the observer or pilot to make pin-point still photographs with the required degree of accuracy or for the personnel to carry out visual observation where it is necessary to spend much time in making a detailed study. This will be especially true if missions are required at low altitude under the clouds in countries similar to Alaska and Siberia, where cloudy weather prevails most of the time.

It is believed that specially designed high-speed, 70-mm. motion picture cameras for observation will solve this problem, in that it will be possible to install a high-speed motion picture camera in the wing or fuselage of an airplane, and operate it over the area to be photographed. Then after the film is printed it can be projected upon a screen for detailed study by the staff. In case it is necessary to complete a detailed study of a line of trenches, railroad yards, docks, or munition depots, it would be quite feasible for the pilot to pass over these areas at 300 mph., press a button upon the control stick, and photograph the entire area in slow motion. After the film is developed and printed, which could be accomplished within one hour the film taken from a plane travelling at 300 miles per hour could be projected upon the screen at the normal projection speed, and afford the staff an opportunity to study the area as though they were drifting over the area at a speed of ten miles per hour. Making the observation pictures in this manner, upon 70-mm. film, twice the width of the standard film, would offer another advantage, in that it would be practicable to cut one or more frames from the film and study them singly or in pairs if a stereoscopic study is desired. With the present knowledge of fine-grain developers, it is believed films made in this manner will afford a maximum of detail. The development of this equipment for air use would not present a very difficult problem Heavy color filters would not be necessary for this type of aerial photography, so that using supersensitive film and a high-speed lens the combination should work out quite satisfactorily. Another advantage is that this equipment could be operated by remote control in single-seat planes and thereby afford a minimal target.

Further, this same principle in the form of very large cameras covering many square miles of territory, could be utilized upon larger airplanes at great altitudes. Recent aeronautical developments have conclusively shown that such planes may be given as high a speed as any other type. Once in the air at great altitudes these planes could be successfully attacked only from the air, making them invulnerable except to planes carrying the same weight of fire.

What has been said above is a somewhat sketchy outline of the vast amount of aerial motion picture activity now being carried out in the various departments of the Army Air Corps. By far, the majority of this work has and will continue to involve technical and tactical knowledge and experience exclusive to the Air Corps, and this work must, therefore, in the interests of efficiency and economy continue unobstructed from any source in the hands of the agency most able to perform it.

NOTE ON THE MEASUREMENT OF PHOTOGRAPHIC DENSITIES WITH A BARRIER TYPE OF PHOTOCELL*

B. C. HIATT AND C. TUTTLE**

Summary.—*In discussing the use of a photocell for the measurement of diffuse density, the importance of the optical characteristics of the cell as a part of the optical system of the densitometer is emphasized. Data showing some of the discrepancies in density measurement resulting from these optical characteristics are given. It is shown that for two extreme types of emulsion, the measurement of diffuse density is possible with certain arrangements of the optical system.*

The barrier type of photocell has been used successfully in many instances as a convenient means for measuring illumination and brightness. Several characteristics of this device, which make it suitable for photometry, appear to make it equally suitable for densitometry. Simplicity, inherent stability, and spectral response characteristics are the leading factors which favor its use for the measurement of photographic density. While visual densitometry will no doubt remain as the standard for a long time to come, the advantages of physical densitometry are so apparent that the substitution of the photocell for the human eye is certain to become popular, if the photoelectric results can be relied upon to a reasonable degree of accuracy.

It is the purpose of this paper to discuss the influence of the *optical* characteristics of this type of cell when used for the measurement of photographic density. This discussion is of interest regardless of the method used to convert the cell output to density values. It is of equal importance whether the cell is used as a direct-reading device with its output calibrated in terms of density, or whether it is employed in a null-method instrument in conjunction with a calibrated wedge or other intensity-controlling device.

The reliability of any densitometer depends, in the final analysis, upon the means of translating light flux to numerical density values.

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* Presented at the Fall, 1935, Meeting at Washington, D. C. Communication No. 567 from the Kodak Research Laboratories.

** Eastman Kodak Co., Rochester, N. Y.

For the visual densitometer, the human eye and brain match field brightnesses using the setting of a standard wedge or polarizing prism to evaluate the unknown density. For the physical densitometer, it is the current output of a photocell which, properly interpreted, will give a value to the unknown density. The essential difference between these two instruments is that, in the first case, the measuring element, the eye, is not connected with the optical system in a manner which will influence the illumination which it is measuring; while in the second, the cell is a very definite part of the optical system with a definite influence upon the results obtained. An analysis of two elementary optical systems for the measurement of diffuse density will perhaps emphasize this difference more distinctly.

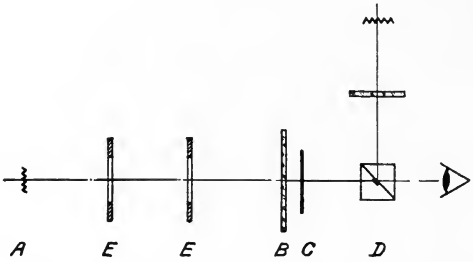

FIG. 1. Optical system of elementary visual densitometer.

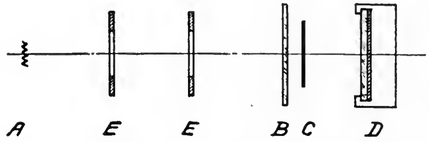

FIG. 2. Optical system of elementary physical densitometer.

Fig. 1 illustrates the essential parts of a visual densitometer. It consists of a light-source, *A*, diffusing material, *B*, film, *C*, the photometer cube, *D*, and the eye. A means of introducing a comparison brightness into the field is shown, although it is not important in this analysis. The apertures, *E*, are merely to limit this field. Light from the lamp strikes the diffusing material. Some is reflected, some scattered, and some transmitted to the film. Here again some is reflected, some absorbed, in proportion to the opacity of the film; and the remainder, passing through the cube, reaches the eye. Some of the light reflected by the film is re-reflected by the diffuser. This added component has very little effect upon high densities, but it causes the low densities to appear somewhat lower than they actually are.

The optical system of an elementary physical densitometer, shown in Fig. 2, is essentially the same as that of the visual densitometer, except that the photocell is substituted for the eye and cube. The behavior of the light is similar to that of the former system, until it passes the film. Here, however, the difference between the cell and the eye as part of the optical system becomes evident, and the optical characteristics of the cell have a decided influence upon the results.

The most striking characteristic of the cell to be considered is reflection. Much of the light passing through the film is reflected by the cell surface, and again passes through the film to be re-reflected by the diffuser. The result is that low densities appear to be higher than they actually are. For example, assume that the surfaces of the cell and the diffuser each reflect 50 per cent of the incident light. If the light that passes through the diffuser is regarded as 100 per cent, then the cell, with no density in place, will be affected by this 100 per cent, plus the components of first, second, and subsequent reflections, amounting to nearly 35 per cent. Now, if a density with transmission of 80 per cent is placed over the cell, the light reaching the cell will be 80 per cent plus about 15 per cent resulting from reflected components that have twice passed through the film. Thus, it happens that the apparent density of the film will be approximately 0.15 and not 0.10.

Another cell characteristic that has an important effect upon the results is the variation of the cell response with the angle of incidence of the light. This characteristic influences the integration of light received upon the cell surface from light-scattering materials. A typical curve of cell output *vs.* angle of incidence is shown in Fig. 3.

A third characteristic, that of spectral response, may be important in that the cell does not exactly match the eye in this respect, and that there is a difference between individual cells of the same or different make. However, this characteristic has little or no significance if the materials to be measured are as spectrally nonselective as the silver image of a photographic film.

A fourth characteristic is better called an imperfection. It has been noted with certain cells that the output is not proportional to the product of intensity times illuminated area. Cells exhibiting this fault have, perhaps, been mistreated during use, or contain some flaw in the surface. It is possible to select a cell that does not show this fault, but since it does exist and may have considerable effect upon results, it has been included in this list.

A fifth characteristic may be called fatigue effect. When cells are subjected to high intensities, there is, at first, a rapid falling off of galvanometer response, gradually lessening, and finally reaching a minimum. The recovery time is much slower, so that if the cell is first allowed to reach a steady state, it will remain reasonably constant while in use.

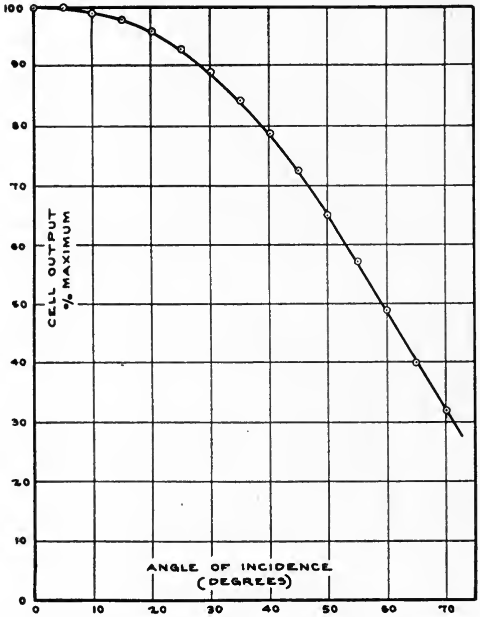

FIG. 3. Output of cell as function of angle of incidence of light.

Combinations of two or more of these characteristics in various degrees may cause idiosyncrasies in a photoelectric densitometer. For this reason, it is of interest to show how the measured value of a photographic density varies as the optical characteristics of such a densitometer are changed.

There are two ways in which a physical densitometer may be calibrated. The first method is applicable to either a null-method instrument or one of the type described above. The instrument may be calibrated with samples of film which have been measured with a visual densitometer. The wedge setting or meter deflection may be marked to correspond to the density value of the film sample. The second, based upon the fundamental definition of density, consists in measuring the illumination of the system with and without the film in place, and computing the apparent density from the formula:

$$D = \log_{10} \frac{I_i}{I_t}$$

It does not necessarily follow that an instrument calibrated by the first method will give the same value to an unknown density as will an instrument calibrated by the second. Nor is there any assurance that either instrument will read correctly a density of an unknown emulsion. Differences in the optical characteristics of the eye and cell, of the optical systems used, and of the various types of emulsions are factors which may lead to erroneous results. However, it may be possible to adjust these factors so that the instrument will give results for all types of emulsions which will correspond to the standard values of a visual densitometer. Such was the aim of this experiment.

The first step was to construct a simple densitometer, similar to that shown in Fig. 2, with the addition of a lens to utilize the light more efficiently and a diaphragm to control the maximum cell output. A commercial Weston photronic cell was chosen, and was calibrated with the galvanometer to be used to determine the relation between light-intensity upon the cell and galvanometer response. This relation was used in the calculation of film transmission and apparent density value. Two types of emulsion were chosen, fine-grained and coarse-grained. The density values were measured with a Jones densitometer[1] to obtain the standard diffuse densities.

Specifically, the aim of this experiment was to devise an optical system in which the density values for both fine-grain and coarse-grain film would correspond to diffuse values obtained with the Jones densitometer. The results are shown, therefore, in such a way that the differences between diffuse and observed density values will be most clearly indicated, and the effects of changes in the optical system most easily recognized.

The first group of results is shown in Fig. 4. Here, the film is sandwiched between the glass window of the cell and a mask, diffusing material being used or not as indicated. There are three facts to be noted about these results: First, diffuse density values are not obtained; second, the two materials do not show the same discrepancies; and third, the results where no diffusion is used correspond more closely to the standard density values, while those with diffusion are considerably higher. The discrepancies are evidently caused primarily by interreflection between cell surface and diffusing material.

In an effort to get rid of the effects of interreflection between film and opal glass, the cell was removed to a distance from the film and diffusing material. With this arrangement, the cell would measure the brightness of the film, and yet be so placed that its reflection characteristics would have little or no effect upon the results. The curves of Fig. 5 show that, for the fine-grain film, diffuse density values were achieved using either flash or pot opal. This was true also for the coarse-grain film, but for a limited range only. With no diffusion, the curves are considerably higher than in the former case. Also, the efficiency of this system was very low. The maximum cell output with diffusion in the light path was less than 1 per cent of that with no diffusion. This is an important factor for two reasons: First, efficient use of light with high cell output allows the use of a more rugged type of electrical meter; and, second, the wattage of the lamp should be kept within reasonable limits to prevent burning the film. It, there-

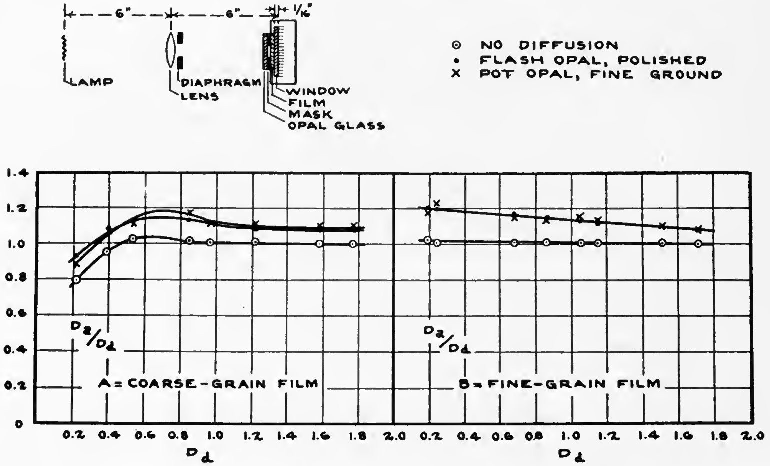

FIG. 4. Diffuse density (D_d) *vs.* ratio of apparent to diffuse density (D_a/D_d) for optical system No. *1*.

fore, seemed advisable to attempt to measure diffuse density with no diffusing material in the system.

In photographic printing, diffuse density will result if the exposure is made with diffuse light; or, as in the case of contact printing, if the positive receives all the light passing through the negative, whether the incident light be specular or diffuse. In a visual densitometer, the eye has no power to integrate light over an angle. Therefore, to read diffuse density, some diffusing material must be used. In a physical densitometer, however, the photocell may be able to integrate light, in a manner similar to the positive material in contact printing, and, therefore, measure diffuse density with no diffusing material in the system.

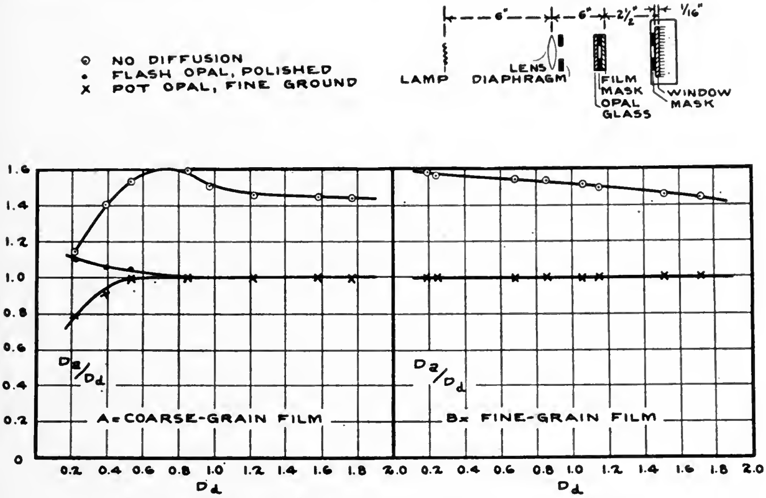

FIG. 5. Diffuse density (D_d) *vs.* ratio of apparent to diffuse density (D_a/D_d) for optical system No. *2*.

In Fig. 4, the cell was placed so that it received nearly all the light passing through the film, with the result that diffuse values were actually achieved in some cases, and very nearly so in others. By substituting a thin glass window for the relatively thick one originally protecting the cell, results were obtained as shown in Fig. 6. For fine-grain film, the density values are diffuse over the entire range. Some difference in the characteristics of the two types of film caused the low densities of the coarse-grain film to appear lower than the diffuse value. Coarse-grain film is known to scatter light more than fine-grain film at low densities.[2] That this is not the cause for the present discrepancy can be deduced from the fact that the curves for flash and pot opal are very nearly parallel to that for no diffusion and show the same droop in the curve at low densities.

After measurement of the reflection characteristics of the film and photocell, it was concluded that a difference in the specular reflection coefficient of fine-grain and coarse-grain film at low densities was responsible for the discrepancy. Accordingly, the glass window was removed entirely, with results shown in Fig. 7. The system measures diffuse density for both fine-grain and coarse-grain film over the range of densities used. However, it is not a system that could be used in practice, since with no window, the delicate cell surface would be exposed to injury. The only advantage of removing this window was the elimination of specular reflection from the glass surface. It was found that this same advantage would result if the glass surface were dulled by grinding. A thin window with a finely ground surface was placed over the cell surface. The results differed in no way from those shown in Fig. 7.

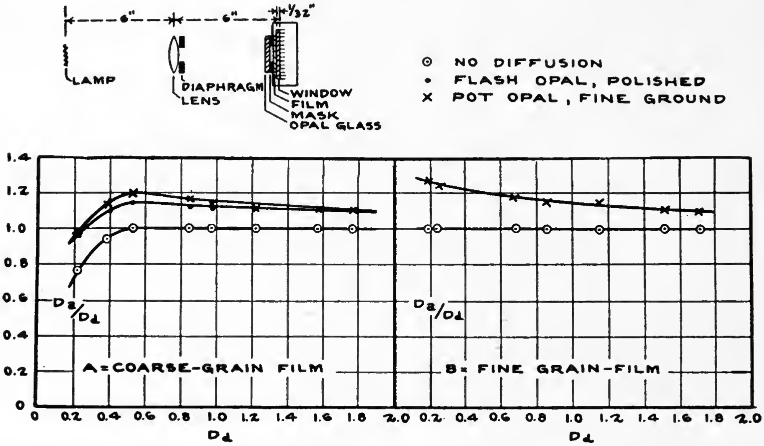

FIG. 6. Diffuse density (D_d) *vs.* ratio of apparent to diffuse density (D_a/D_d) for optical system No. *3*.

The above discussion has illustrated some of the problems encountered in the measurement of photographic density with a photocell. It shows that the characteristics, and even the positions, of the component parts of the optical system have an important influence upon the results obtainable. While not a conclusive proof, it demonstrates that in one case at least, diffuse density, as defined by a visual densitometer, can be measured for two extreme types of emulsion. Finally, it emphasizes that the photocell is in every respect a part of the optical system of a physical densitometer, and must be so treated in the design of such an instrument.

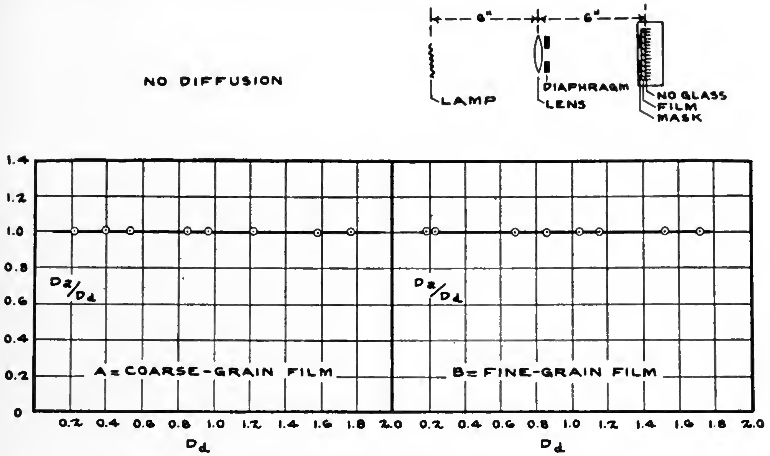

FIG. 7. Diffuse density (D_d) *vs.* ratio of apparent to diffuse density (D_a/D_d) for optical system No. *4*.

REFERENCES

[1] JONES, L. A.: "An Instrument (Densitometer) for the Measurement of High Photographic Densities," *J. Opt. Soc. Amer.*, **7** (March, 1923), No. 3, p. 231.

[2] TUTTLE, C.: "The Relation between Diffuse and Specular Density," *J. Opt. Soc. Amer.*, **12** (June, 1926), No. 6, p. 559; republished, *J. Soc. Mot. Pict. Eng.*, **XX** (March, 1933), No. 3, p. 228.

DISCUSSION

MR. WHITE: The limitations that have been pointed out in this paper are real limitations, and I want to point out that we found this densitometer of value only after calibrating the wedge. When we use a photometric density calibration of the wedge, the final measured densities of a test-strip do not agree with usually measured densities because of the limitations mentioned.

The only feature we found that made it of value was that, with commercial films, the range of graininess was not great enough to cause trouble. We found one calibration that would work to the necessary precision on the various films of commercial graininess.

MOTION PICTURE FILM PROCESSING LABORATORIES IN GREAT BRITAIN*

I. D. WRATTEN**

Summary.—*Current practices and equipment in use in the motion picture processing laboratories of Great Britain are described under the headings: Picture Negative Development, Positive Development, Development of Sound-Track Negative, Developing Equipment, and Printing.*

The developing and printing of motion picture film in Great Britain is done in about thirteen laboratories, only five of which, however, are equipped for developing picture negative film. All are situated in or near London.

There has been a notable increase in the number of British productions during recent years, but the majority of the work done by most of the laboratories lies in printing American productions for release in England. It is the purpose of this paper to describe some of the methods and equipment used in the laboratories in this country.

The smaller laboratories still use a visual method of controlling positive film development, which is, of course, dependent upon personal judgment. The larger laboratories, however, are now using sensitometric means for the control of development, similar to those used in Hollywood.[1] For this purpose the Eastman Type *IIb* sensitometer,[2] a time-scale instrument designed especially to meet the needs of the motion picture laboratory, is recognized in England as the standard motion picture sensitometer. At the present time four laboratories have installed and are using such instruments. Both the Eastman[3] and the Martens head polarization densitometers are widely used. A photocell densitometer complete with automatic curve plotter built by W. Watson & Sons, Ltd., London, has been installed at one laboratory and has given excellent results over a six months' trial period.

Picture Negative Development.—The practice followed in the larger

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Kodak Ltd., London, England.

laboratories is to control the action of the developer by varying either the replenishing rate or the machine speed, according to the results attained by developing, at frequent intervals, negative film strips exposed to the negative setting of the type *IIb* sensitometer. The picture negative itself is developed by the test-method. In using this system a test piece from each roll of picture negative is developed to the normal gamma value, which in most laboratories appears to be in the neighborhood of 0.65, and the man in charge of negative development then determines by personal judgment the development time required by the particular roll from which the test piece was taken. One laboratory, however, attached to one of the largest studios, develops all studio picture negatives to a standard gamma of 0.65.

The formula used for picture negative development is in all laboratories a borax developer of the Eastman *D-76* type, with slight modifications to suit the varying conditions found in different types of continuous developing machines.

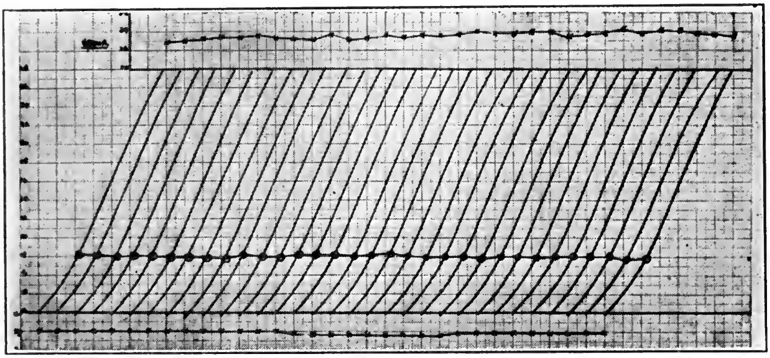

FIG. 1. Sensitometric control record for positive film.

Positive Development.—In the smaller laboratories the development of positive prints is still controlled by the personal judgment of the man in charge of the department. By varying the time of development within certain limits, the machine operator attempts to compensate for developer exhaustion and also for small errors in printer timing. The larger laboratories, however, control positive development by sensitometric means, the practice being to maintain a predetermined gamma by altering the machine speed or the replenisher flow according to the indications obtained from sensitometric exposures on strips of positive film which are run through the machine at hourly or half-hourly intervals. The gamma to which prints are developed varies somewhat from laboratory to laboratory, but it is safe to say that the lowest value adhered to by any laboratory in England is about 2.10, and the highest, 2.40. A positive control sheet from one of the laboratories is shown in Fig. 1. This shows quite clearly that over a period of sixteen hours, during which the machine processed about 170,000 feet of film, the maximum variation of gamma was from 2.28 to 2.40, and the variation in time of development necessary to maintain the gamma within these limits was from $3^1/_2$ to $3^1/_4$ minutes.

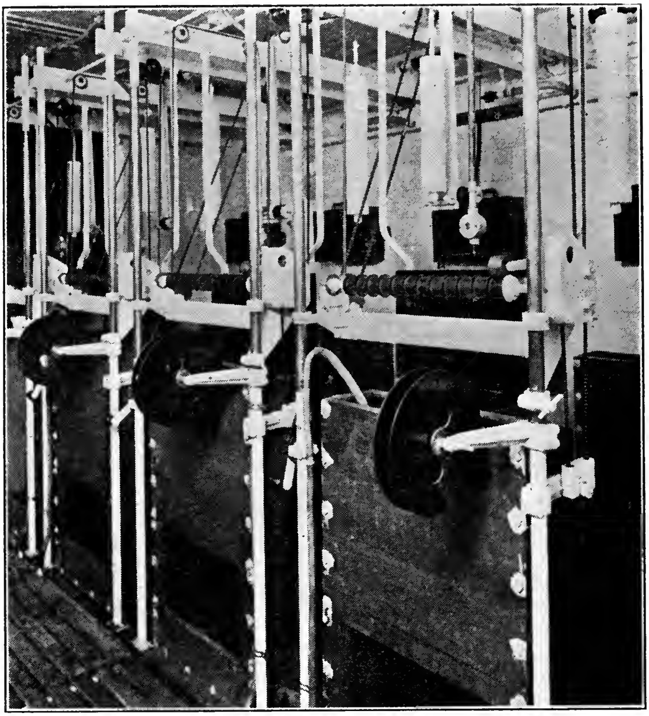

FIG. 2. Vinten developing machine.

The developing formulas vary considerably, but nearly all can be said to be modifications of the well known Eastman *D-16* formula, although in most cases the citric acid contained in that formula is omitted.

Development of Sound-Track Negative.—It is unnecessary to describe the development of the sound-tracks, since the methods used are similar to those already described for picture negative and positive film. It is usual for the laboratory to adhere to the specifications given either by the studio or by the manufacturers of the particular sound system.

Developing Equipment.—Since the equipment used for developing motion picture film in England varies considerably in design, it is thought advisable to give a general description of several different types of installation. Some of the laboratories use the Vinten continuous developing machines, which are designed so as to be readily adaptable to existing buildings with the minimum alterations. For instance, the machines require rooms only nine feet high, and the rooms need not all be on one floor. In the standard machine the range of developing time, from three to eight minutes, is effected by a change in speed of the film drive. Each machine, assuming that

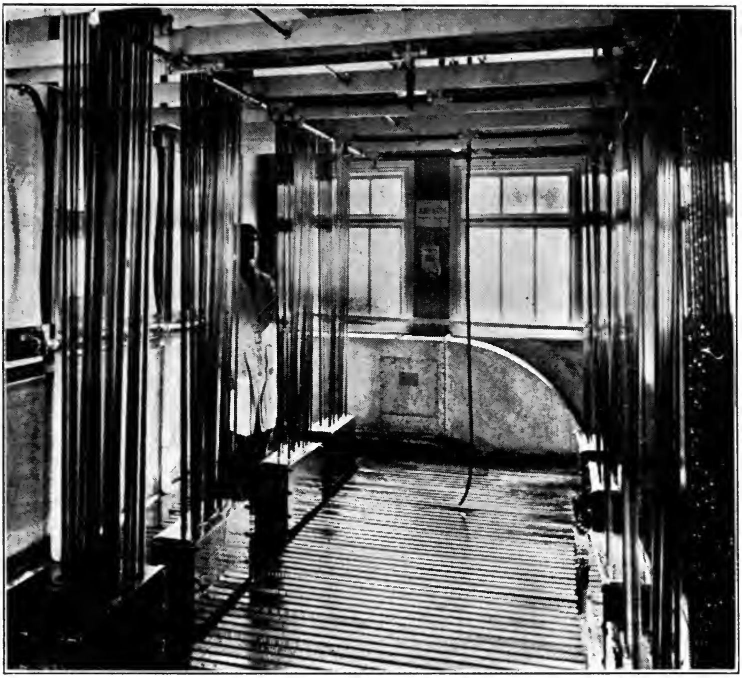

FIG. 3. Washing room for positive film.

a development time of four minutes is required, has an output of 2250 feet per hour. Fig. 2 shows the developing tanks, on either side of which are steel columns. Attached to these columns is the sprocket drive shaft, which is driven by the vertical chains. The sprocket shaft slides up on the two columns for the initial threading up of leader film. In threading, the film is passed beneath the weighted roller of the first sprocket, with the emulsion outward, then down into the tank and up to the next sprocket, and so on, a weighted diabolo hanging in each loop of film in the tank. After development, the film passes into the next compartment for rinsing and fixing. The rinsing and washing are done by fine jets of water directed upon the films as the latter hangs suspended in the tanks, as shown in Fig. 3.

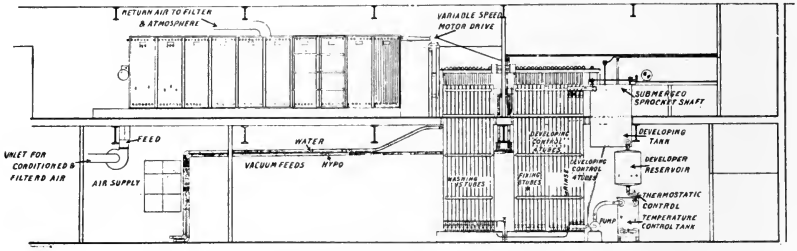

FIG. 4. Lawley automatic developing machine.

A suction nozzle removes all surplus water from the film before it enters the drying room. In this room diabolos which hang in the film loops are placed in racks which prevent them from swaying. Conditioned air for drying the film is fed through ducts along the sides of the room. Most laboratories using this type of equipment employ some form of developer circulation and temperature control. It is understood that no less than fifty-seven of these developing units have been made by the manufacturers.

An interesting design is illustrated in Fig. 4. This type of plant is installed in one of the largest laboratories attached to a studio. The design makes use of long tubes for all parts of the process with the exception of the initial stages of development, for which a large tank is used, and the operation of drying the film, which takes place in the conventional cabinets. The developer circulation system is shown in the diagram. The solution passes at the rate of twenty gallons per minute through a thermostatically operated temperature control tank to a main reservoir, and thence to the tank in which the film is developed. From there it passes into the four developer tubes and is then pumped through the temperature control tank. Developer replenisher solution is fed from the inlet side of the pump. In the case of the washing tubes, the water enters at the bottom of each tube and overflows at the top into a suitable gutter. There are thirteen of these tubes, and since a relatively small volume of water is involved and the rate of flow is rapid, it will be seen that this is a fairly efficient method of washing the film. The machine drive is situated between the drying cabinet and the washing tubes, and is fitted with a variable-speed gear.

The speed at which these machines run is in the neighborhood of sixty feet per minute. In this connection, an interesting feature is the control of development time, which is done without altering the machine speed. Variation in development time is attained by means of the four developer control tubes and four corresponding tubes on the end containing the fixing bath. Each developer control tube has its corresponding fixing control tube, and the pair of tubes contains only a single loop of film between them; so that if developing loop No. *1* is immersed only one quarter the length of the tube, the loop in the No. *1* fixing control tube will be immersed for three quarters of the tube length. Alterations in the length of film in each tube are effected by pressing a small lever, which releases a clutch mechanism and allows the film to pass into or out of the developer tube. Indicators show the length of the film loop in each tube.

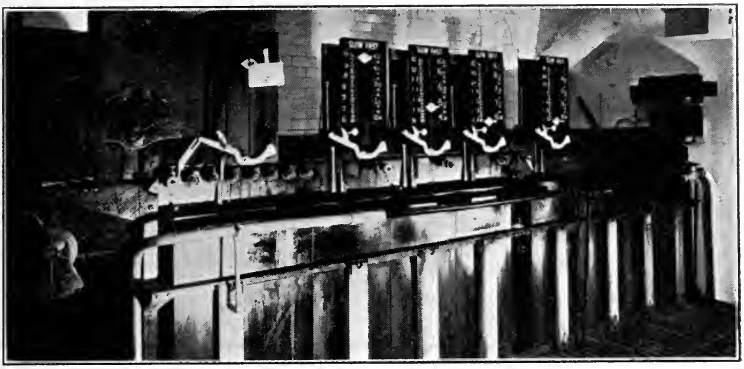

FIG. 5. Debrie automatic developing machine for negative film.

A vacuum suction system removes the fixing solution from the film surface as the film passes into the final wash. The surface moisture is removed in similar manner before the film passes into the drying cabinets. At the entrance of each drying cabinet is a sprocket; all the other spindles bear rollers. A pivoted arm with rollers is located at the bottom of each cabinet, by means of which the film tension is automatically adjusted. Twenty of these Lawley machines are used in the laboratory referred to, and although some of them differ materially in respect to the developer recirculation systems and the drying methods used, the fundamental design is similar in all cases.

One of the largest laboratories in this country uses Debrie equipment. The developing end of one of these machines is shown in Fig. 5, this particular machine being used for developing picture negative film. The time that the film remains in any solution is made known to the machine operator by the control boards at the top. Alterations in the time of development or of fixing may be made by moving a lever upon the appropriate control board, which is calibrated in minutes and seconds. The speed of these machines is in the neighborhood of 25 feet per minute per unit. Fig. 6 shows the washing and drying ends of fourteen of the positive machines. A feature that is usual in most developing installations in this country is the

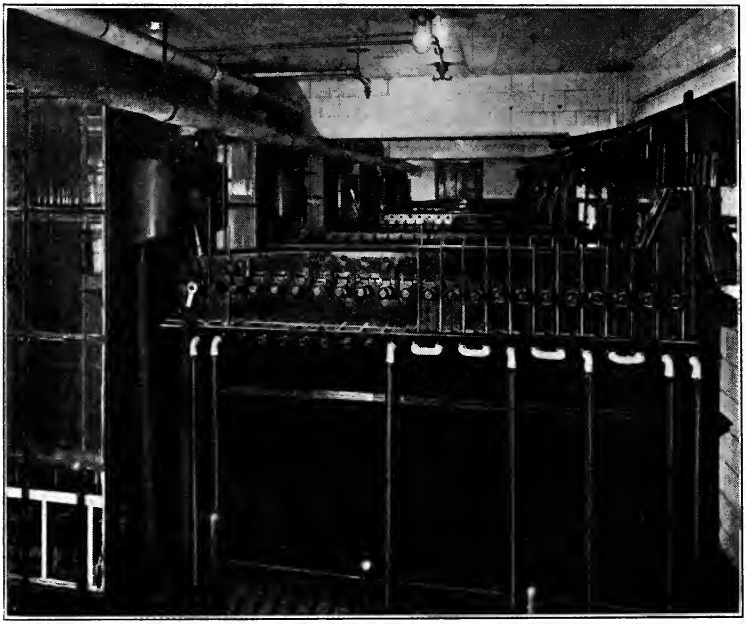

FIG. 6. Washing tanks and drying cabinets on Debrie machine.

provision of a wall dividing the developing machine into a dark end and a light end. A Carrier installation is used for conditioning the air for these cabinets and also for controlling the temperature of the developing solutions.

While the various machines so far described operate at a lower speed in feet per minute than is usual in the U. S. A., one laboratory has built three positive developing machines, each designed to give an output of from 180 to 200 feet per minute. It is believed that, to date, this is the fastest output for one machine operating upon a commercial scale in any country. In these machines, which were designed and built by the laboratory itself, the film is driven by frictional means and the film perforations are not used. Each machine uses 260 gallons of developer and fifty gallons of replenisher solution for developing 180,000 feet of positive film in seventeen hours. Each machine has a separate circulation system and temperature control, and elaborate precautions are taken to safeguard the machines against breakdowns during a run. So successful have the machines been that four more are in course of construction.

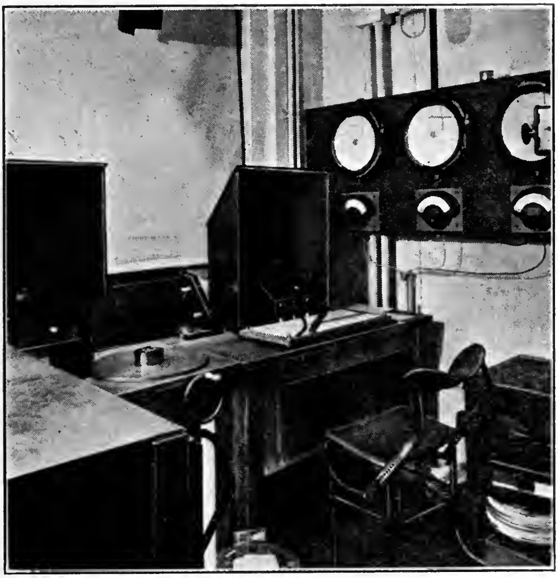

FIG. 7. Control room.

The control of development is the responsibility of a sensitometry department, which controls the machines according to curves plotted from exposures on the Eastman Type *IIb* sensitometer, passed through each machine at half-hourly intervals. Fig. 7 shows a corner of the control room, with Eastman densitometers and a machine indicator panel bearing the instruments for indicating the time of development and the temperature. All instructions dealing with machine control are telephoned from the control room to the machine operator, who has no responsibility other than the mechanical care of the machines.

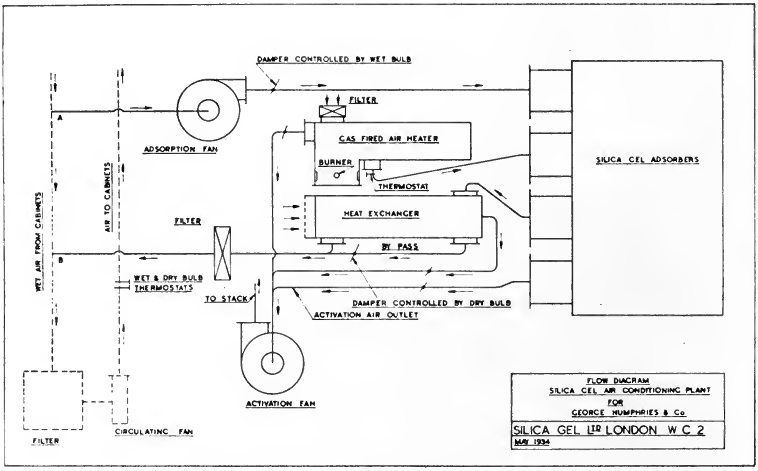

FIG. 8. Silica gel air-conditioning plant.

Among many interesting features of these high-speed units is the use of a closed-circuit silica gel air-conditioning plant for film drying, the flow diagram for which is shown in Fig. 8. The main air circuit—passing through the cabinets, the filter, the circulating fan, and back to the cabinets—is shown in dotted lines at the left of the diagram.

At *A*, in the wet-air duct from the cabinets, a certain volume of air is withdrawn by means of the adsorption fan and is forced through the silica gel adsorbers back to the wet-air duct at *B*. That is, the silica gel plant is in parallel with the main circuit between *A* and *B*, and the moisture evaporated from the film in the cabinets is removed in the silica gel adsorbers from the air withdrawn at *A*. A completely closed circuit thus results.

In the duct leading to the cabinets are placed wet-bulb and dry-bulb temperature regulators, the former of which controls the volume of wet air passed to the adsorbers, while the latter regulates the dry-bulb temperature in the circuit in the following manner: The air entering the adsorbers is heated, first, by the heat of adsorption, which is greater than, but mainly due to, the latent heat of the water vapor removed by the silica gel being converted into sensible heat;

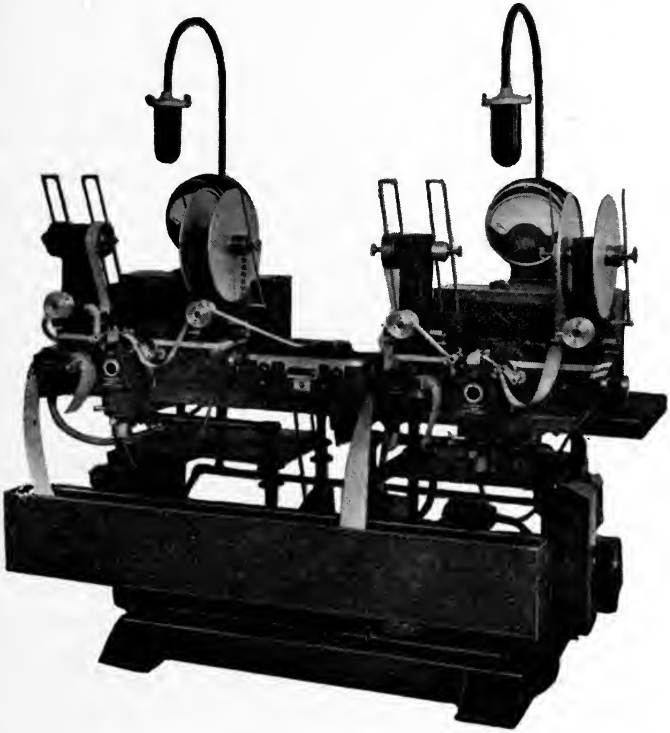

FIG. 9. Continuous printer for sound and picture records.

and, second, by the heat left in the gel after activation. As more heat is thus generated in the adsorbers than is required to evaporate the moisture in the cabinets, the air must be cooled somewhat before it is returned at B. The cooling is done in the heat exchanger, by atmospheric air flowing in counter current to the dried air and exhausted to the stack by means of the activation fan, the by-pass damper regulating the temperature by controlling the amount of dried air passing through the exchanger.

There are four silica gel adsorbers, which function in the following manner: The air to be dried passes through two of the adsorbers in parallel, while the remaining two are being activated. The change-over from activation to adsorption and *vice versa* is, however, done by only one adsorber at a time, so that a very smooth continuous drying effect is attained. The valves controlling the flow of adsorption air and activation air rotate continuously, opening and closing the ports to the various adsorbers in turn. The hot air to any adsorber is thus completely shut off before adsorption air is admitted.

Activation is accomplished by atmospheric air heated in a tubular gas-fired heater. The air is drawn in through the filter located on top of the heater, and its temperature is regulated by a thermostat at the outlet. The wet air from the adsorbers, in addition to the products of combustion, are exhausted to the atmosphere by the activation fan.

Printing.—There is a wide variety of types of apparatus used in England for printing motion picture film. The Bell & Howell model *D* and the Debrie printer, the latter being of the intermittent type with a continuous printing attachment for sound-track, are used by two of the largest laboratories. Another large laboratory uses a modified form of the Lawley printer. This English designed printer is of the continuous type, and has a printing speed of ninety feet per minute. Another make of printer is illustrated in Fig. 9, which is also of the continuous type. The double unit shown prints both picture and sound at the rate of 100 feet per minute. The automatic light change is effected by means of a fiber chart 70 millimeters wide, which runs at a speed one-hundredth that of the negative to be printed. Negative exposure is timed by running the picture negative and the fiber chart upon a special machine in which the chart and the film run synchronously at their proper speed relation. A light change is effected by means of a punch hole in the chart, and the position of the hole relative to the width of the chart determines the printer step value. There are twenty-one light changes.

In all English laboratories except those in which Bell & Howell printers are used, printer light changes are effected by means of external resistances in the lamp circuits. It is customary for the laboratories to match their printers by means of simple photographic photometry in which film stock is flashed at various printer points and then developed and read on a densitometer.

The timing of motion picture film is done by visual methods, and to assist in the operation, the well known Cinex sensitometer is used by two laboratories. Sound-track is timed by density measurement. Printing rooms are conditioned at 70 per cent relative humidity in many of the laboratories.

Conclusion.—From this incomplete description of some of the methods and equipment used by motion picture laboratories in Great Britain it will be seen that the tendency is to follow American practice generally. It must be understood, however, that the number of release prints required of a production is considerably smaller than would be the case in the U. S. A., and that, in consequence, many of the English processing installations were designed with a view to keeping down equipment costs.

There is no doubt that the adoption of the more accurate sensitometric control of development is having a pronounced effect upon processing technic, especially with regard to developer recirculation and replenishment. In this connection it is fortunate that both in the U. S. A. and in Great Britain the Eastman Type *IIb* instrument is regarded as the standard motion picture laboratory sensitometer, since such a condition greatly facilitates an exchange of sensitometric data between the two countries.

The author wishes to acknowledge his indebtedness to Messrs. J. Skittrell, R. Terraneau, W. Hitchcock, W. Lawley, and W. Vinten, and the Silica Gel Co., Ltd., of London, for their kindness in allowing the use of the illustrations for this paper.

REFERENCES

[1] HUSE, E.: "Sensitometric Control in the Processing of Motion Picture Film in Hollywood," *J. Soc. Mot. Pict. Eng.*, **XXI** (July, 1933), No. 1, p. 54.

[2] JONES, L. A.: "A Motion Picture Laboratory Sensitometer," *J. Soc. Mot. Pict. Eng.*, **XVII** (Oct., 1931), No. 4, p. 536.

[3] CAPSTAFF, J. G., AND PURDY, R. A.: "A Compact Motion Picture Densitometer," *Trans. Soc. Mot. Pict. Eng.*, **XI** (Sept., 1927), p. 607.

SPRING, 1936, CONVENTION

CHICAGO, ILLINOIS
EDGEWATER BEACH HOTEL
APRIL 27TH–30TH, INCLUSIVE

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HEADQUARTERS

The Headquarters of the Convention will be the Edgewater Beach Hotel, where excellent accommodations and Convention facilities are assured. A special suite will be provided for the ladies. Rates for SMPE delegates, European plan, will be as follows:

One person, room and bath	$3.00
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	5.00
Parlor suite and bath, for two	10.00 and 12.00

Room reservation cards will be mailed to the membership of the Society in the near future, and every one who plans to attend the Convention should return his card to the Hotel promptly in order to be assured of satisfactory accommodations.

A special rate of fifty cents a day has been arranged for SMPE delegates who motor to the Convention, in the Edgewater Beach Hotel fireproof garage. Private *de luxe* motor coaches operated by the Hotel will be available for service between the Hotel and the Chicago Loop area.

TECHNICAL SESSIONS

An attractive program of technical papers and presentations is being arranged by the Papers Committee. All sessions and film programs will be held in the *East Lounge* of the Hotel.

APPARATUS EXHIBIT

An exhibit of newly developed motion picture apparatus will be held in the *West Lounge* of the Hotel, to which all manufacturers of equipment are invited to contribute. The apparatus to be exhibited must either be new or embody new features of interest from a technical point of view. No charge will be made for space. Information concerning the exhibit and reservations for space should be made by writing to the Chairman of the Exhibits Committee, Mr. O. F. Neu, addressed to the General Office of the Society at the Hotel Pennsylvania, New York, N. Y.

SEMI-ANNUAL BANQUET

The Semi-Annual Banquet and Dance of the Society will be held in the Ballroom of the Edgewater Beach Hotel on Wednesday, April 29th, at 7:30 P.M. Addresses will be delivered by eminent members of the motion picture industry, followed by dancing and entertainment.

INSPECTION TRIPS

Arrangements have been made for conducted tours of inspection to various laboratories, studios, theaters, and equipment and instrument manufactories in the Chicago area. Those firms who will act as hosts on these trips are:

- Burton Holmes Films, Inc.
- Bell & Howell Company
- Chicago Film Laboratories, Inc.
- Da-Lite Screen Company, Inc.
- Enterprise Optical Manufacturing Company
- Herman H. DeVry, Inc.
- Holmes Projector Company
- J. E. McAuley Manufacturing Company
- Jam Handy Pictures Corp.
- Jenkins & Adair, Inc.
- National Screen Service, Inc.
- Western Electric Company
- Wilding Picture Productions, Inc.
- Society of Visual Education

RECREATION

A miniature nine-hole golf course, putting greens, and regulation tennis courts, maintained by the Hotel, will be available to SMPE delegates registered at the Hotel. Details will be available at the registration desk. Special diversions will be provided for the ladies, and passes to local theaters will be available to all delegates registering.

PROGRAM

Monday, April 27th.

9:00 a.m.	Registration Society business
10:00 a.m.–12:00 p.m.	Committee reports Technical papers program
12:30 p.m.	Informal Get-Together Luncheon for members, their families, and guests. Several prominent speakers will address the gathering.
2:00 p.m.–5:00 p.m.	Technical papers program
8:00 p.m.	Exhibition of newly released motion picture features and shorts.

Tuesday, April 28th.

10:00 a.m.–12:00 p.m.	Technical papers program
2:00 p.m.–5:00 p.m.	Technical papers program
	The evening of this day is left free for recreation, visiting, *etc.*

Wednesday, April 29th.

10:00 a.m.–12:00 p.m.	Technical papers program
	The afternoon of this day is left free for recreation and for visits to the plants of various Chicago firms serving the motion picture industry.
7:30 p.m.	Semi-Annual Banquet and Dance of the SMPE: speakers and entertainment.

Thursday, April 30th.

10:00 a.m.–12:00 p.m.	Technical papers program
2:00 p.m.–5:00 p.m.	Technical papers program Society business Adjournment of the Convention

SOCIETY SUPPLIES

Reprints of *Standards of the SMPE and Recommended Practice* may be obtained from the General Office of the Society at the price of twenty-five cents each.

A limited number of reprints remain of the Report of the Projection Practice Committee (Oct., 1935) containing the projection room layouts, and "A Glossary of Color Photography." These may be obtained upon request, accompanied by six cents in postage stamps.

Copies of *Aims and Accomplishments*, an index of the *Transactions* from October, 1916, to June, 1930, containing summaries of all the articles, and author and classified indexes, may be obtained from the General Office at the price of one dollar each. Only a limited number of copies remains.

Certificates of Membership may be obtained from the General Office by all members for the price of one dollar. Lapel buttons of the Society's insignia are also available at the same price.

Black fabrikoid binders, lettered in gold, designed to hold a year's supply of the JOURNAL, may be obtained from the General Office for two dollars each. The purchaser's name and the volume number may be lettered in gold upon the backbone of the binder at an additional charge of fifty cents each.

Requests for any of these supplies should be directed to the General Office of the Society at the Hotel Pennsylvania, New York, N. Y., accompanied by the appropriate remittance.

SOCIETY ANNOUNCEMENTS

BOARD OF GOVERNORS

At a meeting of the Board of Governors held at the Hotel Pennsylvania, New York, N. Y., January 10, 1936, the budget for the year 1936 was drawn up and a complete report rendered by the Financial Vice-President on the financial state of the Society. In addition, further details of the approaching Chicago Convention were arranged as described in the preceding section of this issue of the JOURNAL.

In view of the removal of the President of the Society, H. G. Tasker, to the West Coast, Mr. E. Huse who was reelected in the October balloting to the Executive Vice-Presidency and who also resides upon the West Coast, resigned his position so that another might be appointed to act as executive officer of the Society upon the East Coast. Mr. S. K. Wolf, of New York, was appointed Executive Vice-President, and Mr. Huse was reappointed to the Board to fill the vacancy thus created by Mr. Wolf's appointment.

ATLANTIC COAST SECTION

At a meeting held in the auditorium of the Electrical Association of New York, a paper, with demonstration, was presented by J. A. Miller on the subject of "Millerfilm Recording." The system was originally described at the Hollywood Convention last May, and was published in the July, 1935, issue of the JOURNAL. This presentation included a number of improvements that had been made on the equipment since that time. The meeting was well attended, and the presentation aroused considerable interest and discussion.

MID-WEST SECTION

The regular monthly meeting of the Section was held at the Electrical Association, Chicago, Ill., on January 16th, at which time J. C. Heck presented a paper on the subject of "Screens and Their Applications in Theaters."

The meeting was well attended, and arrangements were completed for the next meeting of the Section to be held on February 13th. Consideration was given also to the activities of the members and officers of the Section during the forthcoming Convention of the Society in Chicago, to be held on April 27th–30th, inclusive, as described in the preceding section of this issue of the JOURNAL.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXVI **MARCH, 1936** **Number 3**

CONTENTS

JOURNAL
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THE USE OF CINEMATOGRAPHY IN AIRCRAFT FLIGHT TESTING*

F. R. COLLBOHM**

***Summary.**—A description of some of the applications of motion pictures to testing aircraft in flight, referring particularly to diving tests, water take-off, landing speed, and load-deflection tests.*

In recent years the flight testing of aircraft has undergone a very radical change. A few years ago the testing of a new airplane consisted usually of one or more initial flights during which the test pilot got the "feel" of the controls and reported whether or not the airplane flew normally and felt satisfactory to him. If something was not exactly right, the difficulty was in most cases solved by a trial-and-error process. After the airplane was pronounced satisfactorily flyable, it was given a full-throttle speed test which may or may not have been corrected for non-standard atmospheric conditions, depending upon the test pilot and the company for which he worked. Usually this was sufficient, but in a few cases was supplemented by a test of the climbing ability and ceiling of the airplane.

Today the flight test department of a modern airplane manufacturer proceeds upon a highly developed, scientific, and technical basis. It is the aim of the flight test engineer to eliminate, or at least to reduce greatly, all the hitherto uncontrolled variables affecting the characteristics and performance of an airplane. The field of flight testing has also become greatly broadened, so that not only are such things as speed, climb, ceiling, and landing speed accurately determined, but also quantitative measures of stability, maneuverability, efficiency, and many other related factors must be determined.

The search for greater accuracy and more coördinated information early brought forth the manifold advantages attendant upon the use of motion picture equipment in flight test work. The early tests with this equipment were so successful that its widespread adoption fol-

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Douglas Aircraft Co., Inc., Santa Monica, Calif.

lowed rapidly. The uses of the motion picture camera may be divide
into three major groups, all of which are closely interrelated and over
lapping. First, the camera is very much utilized as a recording devic
to take rapid, accurate, and simultaneous readings of many instru
ments. Second, it is used as a timing device, either by operating it a
a known, fixed speed, or by photographing the objects undergoin
test in conjunction with a timer or stop-watch. Third, the motio
picture camera has also been used as a direct measuring device b
making use of the geometrical properties of its optical system.

Fig. 1. Set-up of camera for photographing instrument board during dive test.

Dive Test.—An excellent example of the utility of motion pictur
equipment for recording purposes is illustrated by its use in dive test
ing. Airplanes are dive tested in order to ascertain whether all struc
tural parts are strong enough to bear the loads imposed by maximur
design air speed and acceleration. In the case of certain types c
military airplanes, this means that they must be flown verticall
downward until they have reached the highest speed possible, know
as the terminal velocity. When they have reached this speed, the
are suddenly pulled out of the dive; the change in direction cause

a great centrifugal force to act directly outwardly from the center of the turn—in other words, directly downward with respect to the normal fore and aft axis of the airplane. The magnitude of the force or acceleration thus attained is measured in *g* units or the equivalent number of normal level flight loads. For example, when the airplane is subjected to an acceleration of 10*g*, the apparent weight of every item in it is ten times its weight when the plane is flying straight and level. Also, the loads in some of the structural members will be ten times their loads in unaccelerated flight.

During the performance of a test of this type, the pilot is required to record a great number of different measurements, such as, during a dive, the rate of increase of speed, the engine rpm., the control force and the direction, the elevator angle, and the trimming tab angle; at the start of the pull-out, the altitude, and the airspeed; during the pull-out, the maximum indicated acceleration, the control force required, loss of altitude, the elevator angle, and many other related observations. When it is realized that the total time from the start of a dive until the completion of the pull-out is only a few seconds, and that the pilot during this test is under a great strain, not only due to the extreme precision of flying necessary, but also to the severe physiological reactions associated with the high accelerations, it may be readily understood that it is asking too much of any pilot to record all the necessary information.

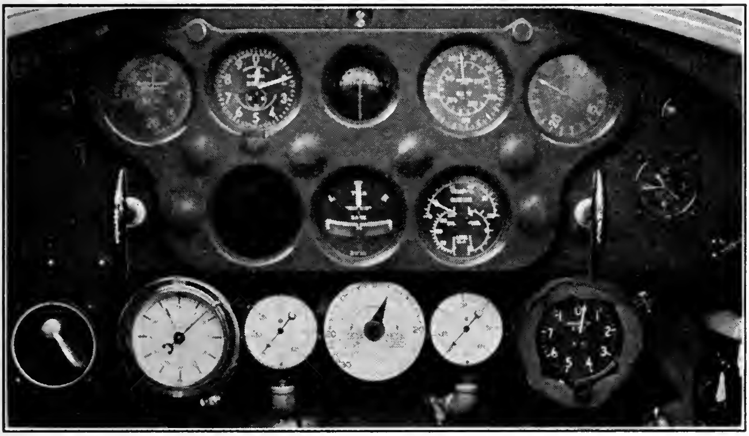

FIG. 2. Special instruments installed for photographic recording of dive test results.

It has been customary in the past to depend upon the pilot's memory for furnishing the necessary data after the completion of the test. This method was necessarily inaccurate and unsatisfactory, so that motion picture equipment was called upon to do the observing. This decision resulted in the development of special remote reading instruments, to be mounted upon the airplane's instrument board together with the regular flight test instruments. These special instruments indicated the control forces exerted by the pilot, the positions of the various control surfaces of the airplane, and other necessary measurements. The motion picture camera was mounted so as to take pictures of all the standard and special instruments, together with a timer, or clock with a large seconds hand, which served as a coördinating measurement against which to plot the variation of each of the other instrument readings throughout the test (Figs. 1 and 2).

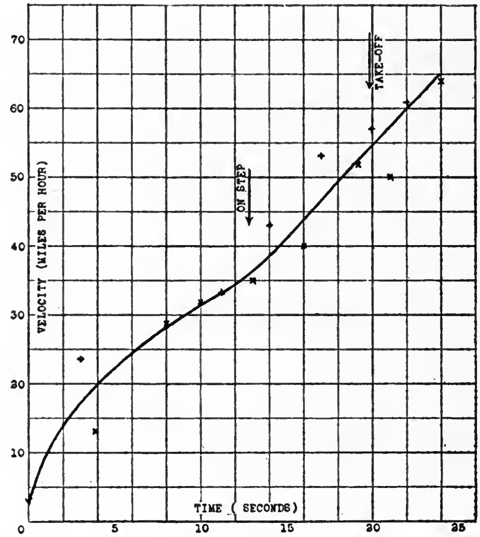

FIG. 3. Speed-time curve for water take-off of flying boat with normal load.

The accomplishment of a system of recording the data photographically was not achieved without having to solve several problems resulting from the high accelerations that were involved. As stated before, during the pull-up each item in the airplane weighs many times its normal weight, including the escapement in the clock and the governor in the camera. Much trouble was at first encountered in keeping the clock going at 10*g* and in keeping the motion picture camera from slowing down and overexposing or even stopping entirely. One type of 16-mm. camera was finally found that seemed to run very consistently and at uniform speed, and it was found that if the clock were rotated about its axis approximately 171 degrees from the upright position it would continue to keep time. However, if moved 1 degree to either side of this new position, it would slow down, and if rotated 2 degrees it would stop completely.

Water Take-Off.—Another type of test depending upon the recording capabilities of the motion picture camera is the measurement of the total water drag upon the hull of a flying boat at any instant during take-off. Here again, the camera is depended upon to record simultaneously several times per second, the readings of many different instruments. As in the dive analysis, all instrument readings are plotted against time, the common factor. The water drag is found as follows:

(*1*) The rate of change of speed, or the slope of the speed-time curve, gives the acceleration at each instant (Fig. 3).

(*2*) Since the weight of the plane is known, the force required to give the above acceleration at each instant is determined ($F = Ma$).

(*3*) Engine horsepower is calculated from the readings of several engine instruments, such as tachometers, manifold pressure gauges, carburetor air temperature indicators, *etc.* This can be further corrected to give the propeller thrust at each instant during the take-off.

(*4*) The total thrust developed by the propellers is divided among several factors: the force required to accelerate the airplane, the drag of the water upon the bottom of the hull, and the drag of the air upon the remainder of the surface.

(*5*) Since the force required to give the observed acceleration is known, it may be subtracted from the calculated thrust, leaving a remainder that counterbalances exactly the air and water drag.

(*6*) Since the air drag at each speed has been determined by wind-tunnel tests and flight tests, it may be subtracted, thus leaving a resultant curve of water drag *vs.* velocity.

This type of test has proved very useful in determining the overload performances possible with flying boats and has shown very close correlation with model tests made in the N. A. C. A. Model Towing Basin. Motion pictures are widely used also to allow closer and more exact analysis of the wave-forming and spray characteristics of flying-boat hulls, both full-scale and in model tests. This is particularly valuable since "slow-motion" analysis is possible.

Landing Speed.—The motion picture camera is used as a timing device for measuring the landing speeds of aircraft. A number of methods are employed for the test, but all are fundamentally the same as regards the function of the camera equipment. One method of determining the true landing speed employs a motion picture camera mounted upon the airplane pointing sidewise, horizontally perpendicular to the thrust line. Equally spaced parallel lines are painted upon the airport field just off the runway and perpendicular to the normal landing path of the airplane. During the landing tests, the camera is started just before the wheels touch the ground so as to take pictures of the parallel lines marked upon the field as the plane passes by them. The landings are so made that the wheels touch the ground when opposite the group of parallel lines, and the point of contact with the ground at each landing is recorded. Before each landing, the camera is fully wound, and between alternate landings the speed of the camera is checked by taking pictures of a stop-watch.

The landing speed of the airplane may then be found as follows: The number of frames on the film from the point at which one of the marks is lined up perfectly to the point at which the next mark is similarly lined up is counted; and, since the number of frames per second is known, and the distance between the lines is also known, the speed of the airplane from each line to the next one can be readily calculated. This speed is determined between each pair of the six or eight lines marked upon the field, and a curve is drawn to show the speed and its variation through that distance. Since the point of contact with the ground was recorded, the speed at that point of the curve is the actual ground speed at the instant of landing. The wind speed is then added to give the true landing speed.

It is important to note that since the camera takes pictures of lines rather than points, the attitude of the airplane has no effect upon the results; even if the camera were not pointing in a direction parallel to the lines upon the ground, it would still indicate when it was exactly in line with one of them because the image of that line upon the film would then be perpendicular to the horizon in the picture.

Direct Measurement.—The use of the motion picture camera as a direct measuring instrument has been more wide spread in European countries than in the United States, but its utilization here for this purpose is progressing rapidly. The accuracy of tests of this type depends entirely upon precise knowledge of the geometrical properties of the optical system of the camera. In other words, the focal length of the lens and the distance to the aperture plate must be known to a high degree of precision. This type of motion picture test can probably be illustrated best by describing a method of determining the landing speed of an airplane. In making the test, the camera is mounted upon the ground in the middle of the landing runway in such a position that the plane lands directly toward the camera, but, of course, comes to a full stop before reaching it. The test consists simply in photographing the plane as it approaches for the landing and until after the wheels are on the ground, with the camera operating at a known constant speed. The distance of the plane from the camera in each frame can later be determined by simple geometry if some prominent dimension of the plane is known, such as, for example, the span of the wings or the distance from one landing wheel to the other. Since the distance between the plane and the camera can be found for each frame, and since the time interval between frames is known, the velocity with which the plane moves toward the camera can be determined in the usual manner by dividing the change in distance between frames by the corresponding time interval. The same procedure has been used also to determine the take-off and the

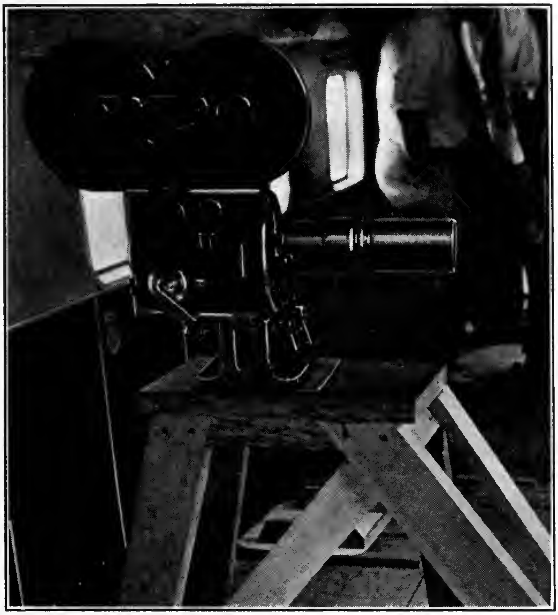

FIG. 4. Installation of motion picture camera in cabin of transport airplane for wing deflection measurement.

initial climb of aircraft, to ascertain their capability of climbing over a fictitious obstacle at some specified distance from the starting point.

Load-Deflection Test.—Another test in which the camera is used as a measuring device in a different manner is that in which the load-deflection curve of a wing or other part of the structure is to be determined in flight. It has been customary in the past to turn an airplane upside down upon the ground and load the wing with lead or sand bags according to a calculated or arbitrarily determined distribution, checking the deflection for various increments of load. The curve of wing deflection *vs.* load could then be plotted and compared with the calculated or theoretical curve. This kind of test was very difficult and expensive, particularly with the larger airplanes, so it was decided to load the airplane structure in the air and measure the wing deflection photographically for each increment of load. Not only did this motion picture test save time and money, but it also eliminated any possibility of error due to variation between the actual distribution of the force upon the wing and the test distribution as applied with lead or sand weights upon the ground. To carry out the test, a standard motion picture camera with a special cross-wire built into the aperture plate was very rigidly mounted upon the center-line of the airplane with the lens pointing directly out toward the tip of one of the wings (Fig. 4). Upon the wing tip were mounted two vertical scales, one near the leading edge and one near the trailing edge, with graduations visible through the camera lens. A visual

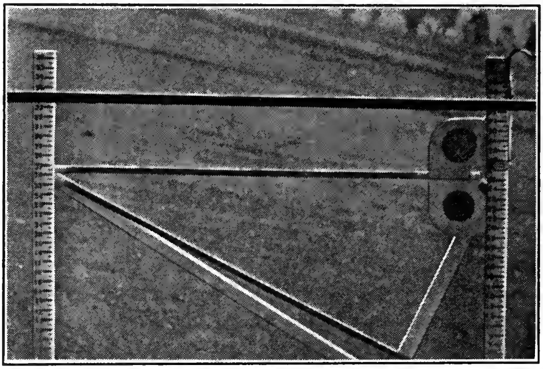

FIG. 5. View through camera, showing wing tip scales with relation to cross-wire in camera, with plane on ground.

accelerometer was mounted upon the instrument board to enable the pilot to pull up the airplane to any desired acceleration, and a recording accelerometer was installed at the center of gravity of the airplane. The plane, which was fully loaded, was then flown at the predetermined airspeed and suddenly pulled up to whatever acceleration was desired. At the same time, the motion picture camera was operated, recording the deflection of the wing tip, both front and rear, by the change in scale position with reference to the fixed cross-wire in the camera aperture plate (Fig. 5). Successive pull-ups were made, each slightly higher than the one preceding, until the maximum proof load was reached, the camera recording the wing deflections for each pull-up. A plot of the data obtained with the motion picture film and the accelerometer records yielded the load-deflection curve ior the wing, together with information as to its torsional stiffness by finding the difference between the deflections of the front and the rear scales upon the wing tip.

WORLD MOTION PICTURE MARKETS*

NATHAN D. GOLDEN**

***Summary.**—A discussion of some of the difficulties of marketing American-produced films in foreign countries, with particular reference to the problems of taxation, censorship, government subsidies for the development of home production, quotas, and contingents.*

During the past few years the motion picture map of the world has had its face lifted in many respects. While formerly our main problem in foreign markets was that of overcoming the language difficulties that followed closely upon the introduction of the sound-film, most of the old problems, such as high taxes, censorship, government subsidies for the development of home production, quotas, and contingents are still with us.

In the early days of sound, the dialog in American films sent to foreign markets was in the English language. Foreign audiences marvelled at the fact that the actors were actually speaking. Of course, only those who understood English were able to derive the most enjoyment from the picture, so that later dialog in the foreign tongue was superimposed upon each scene of the film, the American actors continuing to speak English. Foreign audiences accepted the arrangement at the outset, but soon tired of it and demanded sound-films in their native tongues. This led to the importation to America of numerous foreign actors to do the speaking for the American stars. While the early attempts were, at best, crude, they served the purpose of satisfying the foreign patrons and thus enabling the American industry to maintain its supremacy upon the screens of the world. The next cycle in dubbed films disclosed the demands of theater patrons in non-English-speaking markets for films having more action and less dialog. By that time the art of dubbing was so well developed that a Wallace Berry or an Ann Harding could portray screen

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** *Chief*, Motion Picture Section, U. S. Bureau of Foreign and Domestic Commerce, Washington, D. C.

characters in any language so perfectly that even the foreigners themselves are unable to discover the deception. With dubbing no longer a source of concern for American producers, a new problem in foreign marketing presented itself in the form of legislation designed to curtail the exhibition of dubbed films, insisting that all the dubbing be done in local studios by local actors and technicians. Thus it will be noted that there is a decided trend in foreign countries toward establishing home industries with native actors speaking the mother tongues. Although the films produced thus far are admittedly of an inferior quality, they have nevertheless invariably drawn well at the box-offices because of the appeal to nationalistic loyalty—and despite the fact that the foreign audiences are well aware that their home productions are not at all comparable to those of American origin. The long runs that such foreign films are enjoying at the theaters tend to diminish the number of play-dates for our American films, and, as a result, influence the amount of our business abroad. Reports received from Trade Commissioners at the Bureau of Foreign and Domestic Commerce and the Consular offices of the State Department substantiate these remarks regarding the popularity of local productions and their progress. Confronted with this situation, it may be said to their credit that our American stars and their dubbed pictures retain their popularity and are still the best money-makers for all foreign theater operators.

In Brazil, during the past six months, were exhibited two strictly domestic feature films which gained considerable popular acclaim and proved highly profitable to their producer. The first was a seven-reel feature released during February, under the title of *Hello, Hello, Brazil.* This picture enjoyed the longest run of any feature production thus far made in the country (five weeks) and netted the producers approximately $31,000. Subsequently, another feature film entitled *Students* was released by the same producer, which, while not as popular or profitable as the former, proved a financial success.

The motion picture industry in Argentina during the past few years has developed comparably to those in other countries. A limited number of Spanish-language pictures has been shown, and, judging from the cordial reception accorded the pictures, it is obvious that the natural preference of the Spanish-speaking peoples is for pictures in their own language. During 1934, eight features were produced in Argentina, and it is reported that so far during the current year the total has increased to twelve, with ten more in preparation. It is understood that all the Argentine studios, totalling twenty-one, are wired for the production of sound pictures. No local producer has failed during the past 18 months, and it is estimated that the Argentine production for 1935 amounts to about twenty-two features. It is planned to show these pictures throughout Argentina, and possibly in other neighboring countries, the mother language of which is Spanish.

In Spain the film industry is at present small, but, in spite of financial reverses on the part of some of the companies, steady progress is being made. From a production of five feature films in 1932, the domestic industry rose to twenty-four full-length pictures in the following year. Estimates for 1935 credit local producers with from twenty-five to thirty feature films. Some of the Spanish films have been successful financially, and have indicated the possibility of a bright future for the industry, since Latin America is looked to as offering a great export market for Spanish films when they come into their own. Production thus far has been handicapped by lack of first-class equipment and expert technicians, but the groundwork is being established for an important permanent industry. None of the films thus far produced in Spain deserve particularly high rating, but they have been warmly received by the Spanish public.

Additional competition is expected also from Argentina, where the motion picture industry is developing, as already noted, and from Mexico, as well. Films from those countries, being in Spanish, will undoubtedly enjoy an advantage in Spain. It is important that any films made in Spain should also capture the Spanish psychology, and in that respect Spanish films made in Mexico or Argentina are regarded as more likely to succeed than Spanish films made in the United States.

The quality of the feature pictures produced locally in Finland (in the Finnish language) is generally regarded as decidedly inferior to that of American and European productions. The majority of the pictures, however, have had particularly successful runs because of the natural desire of the Finnish-speaking population of Finland (almost 90 per cent) to listen occasionally to pictures produced in their own language. That a greater number of feature pictures has not been made locally is due principally to the limited capital of the producing companies.

We find that Chinese pictures, with their typically Chinese settings, continue to attract the general populace in China. Only in the case of a few action and comedy pictures has there been any substantial demand recently from the purely Chinese market for American pictures. The extent to which the outlying markets have been taken over by Chinese sound and silent films may be realized from the fact that, in Fukien Province, of 150 pictures imported into Foochow in 1934, 90 per cent were Chinese. Pictures that showed the best box-office returns were those in which the action dominated the dialog. With few exceptions, the most popular actors were also those who depended largely upon pantomime rather than dialog for effects.

There are approximately 40 producing studios in India, according to the most reliable list. A number of Indian companies have made excellent profits on their pictures during the past year or so, which has caused a large number of individuals to go into the picture business for the purpose of making a single picture, utilizing the leisure time of directors, actors, and staff of the studios, and picking up popular Indian plays upon the basis of small royalties or outright purchase. A year ago a run of two or three weeks for an Indian picture was regarded a very outstanding event, but many pictures during the past year have run two to three weeks and in some cases more. In one instance recently an Indian picture was shown for more than 11 weeks.

In Hungary, operators claim that the Hungarian rural districts demand no other than Hungarian sound-films. Listening to a strange language distracts the attention from Hungarian titles, and is tiresome for the average Hungarian theatergoer.

Behind the impetus of production in foreign countries of the world are governmental subsidies granted to producers. It is becoming increasingly difficult for American distributors to release their pictures abroad because of heavy burdens imposed upon them. After all, each foreign market will return only so much money on any given picture, and there are but so many play-dates available.

QUOTAS AND CONTINGENTS

Governmental control of foreign films was introduced in Germany in 1916 as part of a general control of imported products, was continued after the war as a protective measure for the German film industry, and proved to be the forerunner of similar control measures in other European countries. Among the various forms, the best-known controls today are contingents and quotas. Quota laws originally promulgated for the silent films have since been revised to include sound-films. New legislation is designed to stimulate the growth of home industries to be subsidized by means of funds collected from the operation of the quota systems.

There are at present fourteen countries throughout the world that have among their statutes some form of quota or contingent regulations affecting the importation or limiting the exhibition of American motion pictures. Five other foreign countries are agitating for film-control legislation, and in a number of other countries the tax rates are so great that it is difficult for American companies to operate successfully in those markets. In two particular cases, France and Mexico, new regulations recently proposed are so drastic that if enacted they will virtually force American producers to withdraw from the market or turn over their branch-offices to Commissions appointed to take charge of not only the distribution of the film but collecting and allocating the money accruing to the distributors as rental for the films.

In France the present film regulations terminate July 1, 1936. A draft decree has just been proposed, which, if made effective, would replace the present regulations. It would then be mandatory that 30 per cent of all feature films shown quarterly in any given theater be French, and for all films such as newsreels and documentary films the proportion would be not less than 20 per cent. These percentages could subsequently be altered—which would open possibilities in the future of either further curtailment or increase of the number of foreign films that might be exhibited. This draft would further create a National Agency to which deductions would be paid from the net receipts of theaters for authors, composers, and producers as their shares of the receipts. Article *46* of this proposal would give to the Agency absolute powers and the right of handling a large share of all the funds circulating in the French motion picture industry. Our American distributors, in the light of this article, would not only be dependent upon the Agency for the payment of film rentals, but would be subject to the plan of percentage deductions intended to meet the administrative expenses of the National Agency. Any surplus of such deductions could be used to promote the development of the cinematographic art and industry in France. If our American companies were forced to operate under the proposed decree, it would be tantamount to forcing them to contribute money for the creation of a local industry, involving the danger of their being ultimately eliminated from the market.

In Mexico a law has recently been proposed that would create an autonomous organization (Instituto Nacional de la Industria Cinematografica) with a maximum capital of two million pesos ($555,-200), which would be supplied by the Federal Treasury. The object of the organization would be to make loans to worthy Mexican producers in order to encourage the Mexican industry. The proposal is so restrictive that a domestic or foreign company could not operate in Mexico unless it became a member of the organization. One of the most important provisions under which this Institute would operate stipulates that it would have full authority to concede or not to concede permission for the importation of foreign pictures into Mexico. However, before permission would be granted for showing foreign films, it would be necessary to submit the films to the Institute for inspection and revision. Another section of the proposal specifies that the taxes now paid on national and foreign films as importation and exhibition duties would be doubled; but that films exhibited under the auspices of and with the approval of the Institute would pay only half the taxes levied upon other pictures not so approved. Foreign films permitted to enter Mexico would be understood to be exhibited by authority of the Institute.

Under the terms of this proposed law, American films might gradually be eliminated from the Mexican market, and, so far as Mexican business is concerned, our producers would be dependent upon the benevolence of the Institute. American representation through its own distributing organizations would be eliminated, since the distribution of American films would be regulated solely by a governmental agency, the primary purpose of which would be to produce, distribute, and exhibit Mexican films.

As a result of the failure of American companies in Mexico to obtain relief from the high taxes imposed upon them, all companies ceased distributing their product there as of September 30, 1935. Since then, only Mexican and European films have been shown or distributed.

In Great Britain, too, we hear rumblings of a movement for a change in the Quota Act of 1927, which automatically terminates in 1938. An astonishing document has recently been laid before the Film Group of the Federation of British Industries containing amendments to the Act of 1927. The main point suggested in this document as reported by the British trade press, is that at the termination of the existing Act a new Act should be instituted running to 1950, by the terms of which the distribution quota should rise from 30 to 100 per cent of the foreign product for the preceding year. The exhibitor during this period would show an increasing percentage of British product, commencing at 17.5 per cent in 1938 and reaching a maximum of 42.5 per cent in 1950. The proposal further provides that each distributor should acquire in any one year not fewer British films than a stated percentage based upon his foreign film footage registered during the previous year, and that his total expenditure upon British productions should be not less than the same percentage of his total receipts in respect of foreign material.

This virtually means that if a distributor registered in the year 1938 300,000 feet of foreign film, and received in foreign rentals $3,000,000 during that year, for the year 1939 he would be required to register at least 30 per cent of 300,000 feet, *i. e.*, 90,000 feet of British film, and the total cost of such British film would have to be at least 30 per cent of $3,000,000, or approximately $900,000.

While the possibility that the proposals described above may actually become laws is rather remote, the proposals do give us a good idea of the trend of thought of our foreign competitors and the extremes to which they are resorting in their efforts to reduce the screening time of American-made pictures.

CENSORSHIP

Censorship has been the cause of considerable concern to distributors in foreign markets. Without exception, the regulations are becoming more drastic, even to the extent of creating measures to regulate the morals of the public during their attendance at motion picture theaters. An incident in point is a recent consular report from Bagdad, Iraq, advising that the mayor of that city has issued an order to all theaters that "during matinee performances men and women must not sit together, and that during night performances they may do so in boxes and galleries, but not in the second- and third-class sections."

The purpose of this paper has been merely to point out some of the dangers confronting American film producers in a number of the foreign markets. Although some of the statements may seem rather pessimistic, it is not intended to convey the idea that American pictures will reach the point of being completely removed from the screens throughout the world. Striking a more cheerful note, it may be said that quality films will never be submerged, and that though we may lose some screening time as a result of local production abroad, the pictures of high entertainment value that American producers have been turning out, and those having international appeal, will always find a market despite any legislative or nationalistic barriers that may be erected in foreign markets. Present handicaps may mean that we shall send fewer pictures abroad, but such pictures as we do send will return revenues commensurate with their superior quality. Time will supply a definite answer to the questions now at issue. But factual studies are quite convincing that the energy, resources, and producing genius of the American industry will serve to sustain for us a strong position in the picture houses of the world.

TECHNICAL ADVANCES IN SOVIET RUSSIA*

A. F. CHORINE**

Summary.—*A brief description of recent progress in motion picture development in the U. S. S. R. Reference is made to a combined machine for film cutting, sound mixing, and re-recording; a process of recording mechanically upon old film, and the use of such recordings on location and for radio broadcasting; a new continuous battery-operated portable projector; a photocell involving multiple secondary emission; recording sound upon separate film synchronized with the picture film; and transmission of sound pictures by television.*

I am happy to be present at this conference of engineers representing the highest cinema technic in the world. Permit me to convey to you the greetings of the Chief Soviet Cinema Administration and all the scientific and technical cinema workers of the U. S. S. R. I shall try to describe in a few brief words the motion picture developments in which we are engaged today.

With regard to single-film sound cameras, we are working upon a number of small improvements in operation, regulation, *etc.*, one of which relates to an apparatus permitting the director, the recordist, and others to observe how the sound is being recorded while the picture is being shot. The title of the picture and the name of the sound engineer, also, can be printed automatically upon the sound negative, for the purpose of identification.

We have constructed another machine for combined film cutting, sound mixing, and re-recording. This machine has two heads for sound-film, or one for mechanically recorded film, a phonographic mechanism having two different speeds, and a circuit for three microphones. All the connections and combinations of the films are controlled electromagnetically from one keyboard.

All the studios of the U. S. S. R. are now recording mechanically upon old film for the purpose of obtaining on location records of a large variety of sounds, folk songs of the various nationalities, *etc.*

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** All-Union Electrical Trust, Moscow, Russia.

The system has proved desirable because of the negligible, or entirely non-existent, cost; and, in addition, it permits playing back immediately what has been recorded. To test the device the Leningrad Broadcasting System broadcast 70 per cent of their programs with mechanical recordings on old film over a period of three months. The first recordings were of entire operas, performed by the best operatic companies in the Soviet Union, as well as of the best concert performances and news events. The experiment was crowned with practical and technical success.

Efforts are now being made to improve the construction of sound-reproducing apparatus so as to reduce the cost of operation for both large and small theaters.

Great interest is being shown in the Soviet Union in a movement to make sound pictures available to the remotest corners of Siberia, to sections of the North, and to Turkestan, and also to the reading rooms of the collective farms. The chief requirement for such installations is that it should be possible to show pictures, with direct or alternating current, at places where no commercial supply is available. For that purpose I have devised a special system employing a small projector in which the film moves continuously. Owing to the fact that the projector does not have a pull-down mechanism, a very low-powered motor can be used for the drive. The resulting mechanical system is very simple, and can be employed for mechanical recording. The entire installation, including amplifier, projection lamp, motor, *etc.*, is operated by a 6-volt, starting-type battery. Everything is reduced to the utmost simplicity. There is not even a photocell. The apparatus is now being given a field-test, at the conclusion of which a description of the system will be published.

A new type of photocell, involving multiple secondary emission, has been developed for use in sound pictures which is about a million times as sensitive as the previous cells. Samples of such photocells have been made and tested, and substituted in large theaters for all the tubes in the amplifiers except the last. Under laboratory conditions they have given satisfactory results. One shortcoming of the cells at present is the comparatively high voltage, about 2000 volts, that must be applied. There is no doubt that the system has a promising future. I have just learned that Dr. Zworykin has produced a similar cell in the RCA Laboratories.

A theater is Leningrad is experimenting in reproducing mechanically recorded sound from a separate film synchronized with the picture. Such a system would make it possible to show foreign pictures and to equip silent films with sound in very short order.

Laboratory experiments are now being concluded on the transmission of sound pictures by means of television. Use is made of an optical disk with achromatic lenses. The legibility is from 120 to 180 lines. In 1936, experiments will be made in Moscow on the transmission of films on a wavelength of 7.5 meters (4 megacycles). At the beginning of the experiment, 50 receiving sets with cathode screens will be installed in various parts of the city.

Extraordinary interest is being shown in dubbing, because there are no fewer than seventy minor nationalities in the Soviet Union, each having its own language, and each language being spoken by great numbers of persons. A number of these nationalities now have their own cinema studios. It is obvious how very desirable it is to be able to make pictures in the Soviet Union in at least three or four languages.

The Chief Administration's Experimental Factory for Cinema Equipment has recently produced the first experimental perforation machines for printing and developing pictures. Up to now, all such machines were obtained abroad.

Closing this brief report, I extend to you, in the name of the Chief Administration, headed by Mr. Shumiatsky, an invitation to the Conference of Engineers to be held at Moscow in the Spring of 1936 in conjunction with the Cinema Festival. In the near future I intend to submit to the Society detailed descriptions of the apparatus mentioned above.

THE MOTION PICTURE INDUSTRY IN JAPAN*

Y. OSAWA**

Summary.—*A description of the status of motion picture production, distribution, and exhibition in Japan, mainly from a commercial point of view, but with brief reference to some of the operating problems.*

The motion picture has in recent years, in Japan, gradually replaced older forms of public entertainment, such as Kabuki and other stage dramas, and has now established itself in a firm position among the leading industries of the country. According to government statistics, nearly 180,000,000 Japanese visited the motion picture houses during the last year. It is quite evident that the motion picture will become still more important in the public life of the Japanese people in the coming years, and the real growth of the industry seems now to have begun.

Nevertheless, the artistic and technical standards of the Japanese motion picture are still in an elementary state. There are many scientific problems to be studied and cinematic experiences to be acquired. This paper will briefly describe the present condition of the motion picture industry in Japan, sketching its various aspects and problems.

PRODUCTION

During 1934, a total of 440 feature pictures were produced by the Japanese studios: the three major companies, the Shochiku-Shinko group, Nikkatsu, and Daito Eiga producing three-fourths of them; and the minor and independent studios, altogether eight or ten in number, contributing the remaining one-fourth. In the latter group are included the Photo-Chemical Laboratory, more commonly known as PCL, of Tokyo, and J. O. Studio, Ltd., of Kyoto, which are the two new financial interests that came into the motion picture field about three years ago.

Today an average Japanese feature picture is made in 8 to 10 reels,

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** J. Osawa & Co., Ltd., Kyoto, Japan.

whereas until only a few years ago no picture was regarded as a "feature" unless it contained more than 15 or sometimes even 20 reels. The number of release prints usually required for distribution varies from 12 to 15, a sufficient number for circulation throughout the country in the ordinary case. Sometimes, in the case of a particularly popular picture, 20 or 30 copies may be made; but such is the exception rather than the rule.

The yearly consumption of raw film stock in Japan is approximately 50,000,000 feet of positive and 5,000,000 feet of negative. Agfa, Dupont, and Eastman are used principally, Eastman taking a greater share of the business. During the last year, two Japanese companies entered into manufacturing standard motion picture raw film upon a large scale: namely, Fuji Film Manufacturing Company, a subsidiary of the Mitsui interest, and Oriental Photo Industrial Company, an experienced manufacturer of general photographic materials. Both companies have already placed their sample films upon the market, but the quality is not yet sufficiently satisfactory for acceptance by the major companies. Although they have not yet attempted to produce other than positive film, it will still be some time before they offer serious competition to imported films.

The processing laboratories of the major studios are generally rather poorly equipped, with the old rack method still in use, under the visual, or rather temperamental control of the watchman on the floor. However, there are now two modern processing laboratories using up-to-date machine developers with thermostatic control of the chemicals and regular air-conditioning systems. One is the Far East Film Laboratory, in Kyoto, which processes Eastman film, and the other that of the J. O. Studio, also in Kyoto, which handles Agfa film. A new laboratory is now being built in Tokyo by the J. O. Studio, which will begin operating by the end of May this year.

Although the acceptance of the talking picture by the Japanese audience has been quite decisive, production has not kept pace with the public demand, due mainly to the financial weakness of the major studios and to the inability of the theaters to equip themselves with sound apparatus. While many attempts had been made since 1930 to produce Japanese "talkies," a really successful sound picture was not produced until 1932. Since that year the major companies have reluctantly started producing them, but with little progress. It was not until 1934 that "sound" was seriously taken up. Although the progress of sound-film in Japan has been very slow up to this time, 1935 will see a rapid increase in the production of talkies and perhaps by the end of 1936 all the important Japanese pictures will be sound pictures.

While the number of feature pictures produced in Japan is relatively large, the quality of the average Japanese film has not yet attained the high technical and artistic standard of the average American or good European picture. Japanese producers yet have much to learn in the field of story and scenario preparation, subject matter treatment, editing technic, *etc.* Also, an equally important defect is found in the poor working conditions in the Japanese studios, particularly the inadequacy of supply of mechanical equipment and apparatus. The situation is almost tragic as regards sound recording.

Nikkatsu Studio is the only Western Electric licensee in Japan; and J. O. Studio, Kyoto, is the only studio equipped with RCA recording apparatus. Other studios, including Shochiku and PCL, use their own sound systems. Other mechanical equipment and facilities are also sadly lacking in most of the older studios. Such new apparatus as the zoom lens, perambulator, projection background process, fully automatic printer, color process, *etc.*, are still in the realm of luxury, and about which Japanese technicians are allowed only to dream.

The cost of an average Japanese picture is incredibly low. An average talkie, a fair-sized feature picture of 7000 to 8000 feet, with a shooting period of 45 days, is made within a total of between 30,000 to 50,000 yen, including the story, scenario, salaries of director, cameramen, talents, musicians, sound engineers, and all other technicians, sets and costumes, location expenses, royalty for sound recording, *etc.*—in fact, all the items that are necessary in producing a complete picture. The low cost of production, necessitated by the distribution limitations which will be described later, is responsible without question to a great extent for the poor quality of the average Japanese picture.

DISTRIBUTION

There are approximately 2000 motion picture theaters operating in Japan today. Although most of the older houses are very poorly constructed buildings, the new theaters are of very modern design with every up-to-date accommodation. They are air-conditioned and well furnished, with comfortable chairs. According to the latest figures, only one-half of the movie theaters in Japan are now equipped with sound reproducers, leaving nearly 1000 theaters yet to be wired. These additional installations will very likely be made within the next two years. Of the approximately 1000 theaters already wired, only 10 per cent are equipped with either Western Electric or RCA reproducers. About 40 theaters have the Tobis-Klangfilm system, and the remaining 85 per cent have divers other sound systems, both American and Japanese, of rather poor quality.

The average admission fee of a Japanese movie house is 50 sen in the first-run week in the big cities, and 30 to 20 sen in the smaller towns. After the second run, the fee usually drops to 20 to 10 sen. Although the admission fees are low, a good first-run theater with a "hit" program can earn a gross of 20,000 to 30,000 yen in the first week. A very popular film just recently earned a gross of 80,000 yen in a two weeks' run in one theater in Osaka, which was deemed exceptionally good.

The program always consists of two feature pictures with one or two shorts, thus making one performance about three hours long. The theater usually runs four performances a day.

Japanese movie fans can be separated into two distinct categories: the class audience and the mass audience. There seems to be no middle ground between them. Therefore, a Japanese picture must be either an exceedingly fine film of the highest quality, which will be ardently admired by the student and the intellectual classes patronizing the better theaters in the big cities; or it must be a low-level picture with much excitement or pathos which will win strong support from the lower working class constituting the bulk of the movie audience in the smaller towns and in the country. Among the former, such films as *The Chorus of a Million* produced by Victor Japan and J. O. Studio, and *Botchan* by PCL, have been recent successes; for the latter class, love themes or sword fighting plays (corresponding to the Wild West pictures) have always been popular.

Foreign films are generally patronized only by the student and the intellectual classes, except wild animal pictures, which are very popular among all classes. During 1934, 340 foreign feature pictures were released in Japan (80 per cent American and 20 per cent English and European), this number being the highest in the last five years.

With the advent of talkies, the language barrier was at first believed to be a very serious obstacle. In fact, with the early pictures, an interpreter, called a *Benshi*, standing upon the stage in the dark, shouted a translation of the dialog along with the original sound, thus making it nearly impossible for either the original dialog or the translator to be understood. Now all foreign films have their dialog superimposed upon the film in Japanese titles, thus eliminating the interference of the Benshi. Recently two or three attempts have been made to dub the Japanese language into the sound-track. The most successful attempt was made in the RKO picture, *Flying Devils.* Its result was very satisfactory, and there is good possibility of adapting the method in the future to certain types of foreign pictures.

The best received foreign pictures in Japan during the last year were *It Happened One Night, Footlight Parade, Der Kongress Danzt, Le Pacquebot Tenacity, Poil de Carot, etc.* The biggest box-office successes were *King Kong,* Tarzan pictures, and Chaplin and Lloyd pictures. Because of the superior technic and treatment of foreign pictures, the demand for good foreign films will continue.

CONCLUSION

The vital problem facing the Japanese motion picture industry today is the improvement of the technic and workmanship of their films, so that the standard will be raised to the international level in technical quality and artistic treatment. At present, earnest efforts are being made upon the part of certain Japanese producers to coöperate with some American companies in the joint production of pictures in Japan. If such a scheme materializes, it will provide excellent opportunity for the Japanese technicians to learn their lessons and acquire new experiences. Such stimulation will be so great that it may revolutionize the entire production system. At any rate, the Japanese motion picture must develop to a higher level, and it may not be so long before Japan will also be contributing to the other peoples of the world worthy and varied entertainments of the Orient through the medium of the motion picture.

DISCUSSION

MR. E. RICHARDSON: Mr. Osawa, your people are so wonderfully successful with the brush and have such natural technic in artistic lines, I wondered whether in your country they had produced cartoons of your people?

MR. OSAWA: Yes; about three or four companies are now trying to make Japanese cartoons, and some are getting a little bit better. But although they are very successful in drawing pictures, *etc.*, the American system is not as well worked out as in the studios, and as to the music—we haven't very good orchestras. But I think the young boys are working very hard on that, and in a couple of years we may turn out some cartoons.

(*A very interesting Japanese film was projected, showing a number of motion picture studios engaged in production and some of their most celebrated artists in action; also a number of the most prominent motion picture theaters.*)

THE MOTION PICTURE INDUSTRY IN INDIA*

G. D. LAL**

Summary.—*A description of the status of motion picture production, distribution, and exhibition in India, mainly from a commercial point of view, but with brief reference to some of the technical problems.*

Nearly five years ago the first "all talking and singing picture" was produced and exhibited in India. As sound was then a novelty, it took the country by storm. Business conditions generally were far from satisfactory, and so, finding money in the talking pictures, everybody rushed into the business. Within a year about twenty producers had entered the field; and by the end of the second year the number of producers had increased to about thirty-four.

Unfortunately, the technical educational system in India is sadly lacking. Contacts with the rapidly progressing countries of the West, especially America, have been, and are yet, very poor. India has not been closely in touch with western scientific developments. Thus, when the motion picture "gold rush" started, a number of adventurous silent producers, theatrical people, and others began hastily to look for recording outfits. Due to the fact that sound was new and insufficient technical information was available, and being ignorant of the complications thereof and having only limited finances at their disposal, nearly all the adventurers fell an easy prey to the "bootleg" equipment manufacturers.

To date, there are approximately ninety producers in India operating completely under Indian capital and management. There are about thirty sound studios, which, besides producing their own independent pictures, rent their studios and equipments on a footage basis to the other producing companies. The chief centers of activity are Bombay and Calcutta.

Unacquainted with the technic of sound, the Indian writers were incapable of planning or writing their stories successfully. Directors,

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Delhi, India.

actors, and the other technical hands were, and still are, recruited from the silent producers and the theatrical stage. The effect has been to produce pictures that are jumpy, lacking in continuity, and too theatrical.

The sound engineers have come mostly from the ranks of radio enthusiasts or college graduates whose training has been largely of an academic nature. As a result of their unfamiliarity with the equipment with which they had to work, and not being well informed on the principles of recording and its limitations and complications, the sound quality has consistently been very poor. In numbers of cases the quality has been worse than that afforded by some of the midget radio receivers, and poor laboratory work has contributed considerably to its insufficiency. Although some of the studios do boast of possessing an up-to-date laboratory, they have not yet been able to maintain a strict check on photographic density. This, of course, is due to the lack of information not only as to how to operate the equipment properly, but as to the entire processing technic. Even though some studios have managed to improve the sound quality in the film, it has been ruined by the projectionists in the theaters, who are none other than the good old silent "grinders." Most of them do not know even the fundamentals of electricity, not to speak of the principles of sound reproduction.

According to one estimate there are about 600 sound theaters in India; and according to another, there are somewhat more than 700 all over India. The majority of these are the old silent houses or theatrical halls, and have not been suitably treated for sound. About a score or two have been properly treated acoustically. Most of them contain five to seven hundred seats, and nearly all are equipped with American-made reproducers. Very recently a reproducer called "Philisonor," made by Philips of Holland, has come into the market and has been widely distributed. Sales of this reproducer so far seem to indicate that it will become the most popular reproducer in the Indian market. The chief reasons for the small number of wired houses in India are the lack of electric power circuits, lack of system in organizations, and the cost of equipment.

Almost all Indian productions are based upon religious, mythological, and historical subjects. Two of the most progressive producers have very recently begun to produce social plays. To produce religious and mythological pictures effectively, much trick work, playbacks, rear projection, and other devices are required that have not yet been attempted. The trick work that has been attempted so far has been, from the American point of view, very primitive and ineffective. Only recently a few rear projection outfits have been bought by some producers, but no pictures are reported to have been released in which "process shots" have been employed. Two attempts have also been made on animated cartoons, which have been reported to be jumpy and lacking in humor.

Despite the fact that the languages and dialects of India are very numerous, the pictures made in Hindustani have commanded a very large market, the reason being that the majority of the people in the provinces such as Bengal, Madras, Sind (Karachi), *etc.*, having languages of their own, yet can understand Hindustani, though their own languages are not understood outside their provinces. Thus, the belief that the number of languages and dialects in India militates against the possibilities of the motion picture field is incorrect. In proof thereof, it might be interesting to note that pictures produced at a cost of about 20,000 rupees have yielded as much as 75,000 rupees and more. The possible receipts can be envisioned if it is borne in mind that there are only 700 theaters in India; and the educated and respectable families have not patronized the Indian pictures very much because they fall far short of their expectations. Another misunderstanding, referring to the "caste system," should also be corrected. The so-called "untouchables" attend the same theaters, travel in the same trains, street-cars, *etc.*, as the "touchables"; no segregated corners are allotted to them, and they pay the same admission fees.

There is no flat-rate admission system in India—at least it has not yet been introduced so far. The usual charges in rupees are equivalent to $3, $2, $1, 50c and 25c. This classification is not based upon any caste system, but upon the social status of the individual. In order to improve and build up the Indian motion picture industry four courses are open: (*1*) to send *bona fide* students abroad to study the various phases of the industry in other countries; (*2*) to import foreign technicians to assist in practical training and in organizing the industry; (*3*) to purchase standard equipment and seek the information and training through them; (*4*) to organize a financially strong and central organizing body to control the industry.

(*1*) Quite a number of our young men came to America and other countries, and invariably began their studies by joining a technical school. Unfortunately, there is no school that can possibly provide broad and useful practical training in the many phases of this huge industry; and because the boys did not realize the complications and breadth of the art, they believed they could become experts by taking the diplomas of the schools that existed. Most of the boys that came out have gone in for photography and sound engineering; they obtained their diplomas and returned to India as "Foreign Qualified Technicians." Some of the boys who understood the situation and realized that actual practical training in the various studios was necessary, tried to gain entree to the studios, but found the doors shut. The result has been that they had to return to India incapable of being of much help to the industry, although a little wiser in the ways of the world.

(*2*) Due to the various misunderstandings between the East and the West there has been a serious lack of appreciation of the actual conditions of the East, particularly as regards living conditions. The purchasing power of a rupee in India is almost the same as that of the dollar in America; but as the exchange ratio is roughly three rupees to the dollar, it will be appreciated that to pay the American technician his American salary in dollars in India becomes prohibitive.

(*3*) It is most surprising, indeed, that the various manufacturers of standard equipment in America have not yet taken stock of the Indian market. Indian import duties and other local tariffs are very high, amounting in some instances to 30 or 40 per cent. Naturally, the producers find it difficult to pay the high prices for standard equipment and to pay the royalties, in addition.

To expect technical information or other training from the major equipment companies is out of the question unless India is their customer; and even those Indian firms that have been using some of the standard equipment and recording channels have not been able to obtain results because of their inexperience and lack of technical information. Apparently the outfits are working satisfactorily, as they (*i. e.*, the manufacturers) "have no complaints" and "have sold 'so many' outfits." But those who have seen, heard, and watched the results know how satisfactory they have been.

(*4*) One of the chief reasons why capital was shy and why most of the public-spirited men kept aloof from the Indian motion picture industry was the lack of confidence in the technical personnel and their organizers. Furthermore, there has been a tremendous waste in production, which was, and still is, due to the inexperience of the present day directors and technicians, and the absence of really clever and responsible men to suggest workable plans and schemes. What has made the situation worse has been the entrance into the field of the self-styled "Foreign Qualified Technician" and some undesirable hands that have come into the business.

The cost of producing an average length feature, containing about 10 or 11 1000-ft. reels (sometimes as many as 16), is in the neighborhood of 10,000 rupees. Unfortunately, no serious attempt has been made to collect such data and it is almost impossible to quote definite figures.

Since the advent of sound, American pictures have been patronized less than have the English pictures, the simple reason being that the pictures sent to India were of jazz and underworld life, full of typical American slang and humor, which nobody outside America can understand or appreciate. But such pictures as *Cleopatra*, *Queen Christina*, and their like are very popular even among the uneducated.

It is certainly very gratifying and creditable that India has made slow but steady progress in spite of the odds against her. She has been struggling along, groping in the dark, accomplishing whatever has been accomplished by trial and error. Only recently an Indian picture has been accepted for exhibition at the International Arts Exhibition to be held in Vienna. India has the talent, and has everything in her favor in the way of story material, locations, workmen, and so forth. What are lacking are more honest, sincere, and experienced Indian boys to study the industry abroad and become the pioneers in organizing the industry. It is hoped that before long a better understanding and coöperation will be established between the East and the West which will eventually yield better business to the American manufacturers and assist in building up our industry. Thus we shall have not only more friendly business relations, but a more authentic understanding of the East will be gained. Also, the producers here in Hollywood will not have to send out expensive expeditions to the East or the Far East, or to Africa, for background shots which could very safely be entrusted to producers or individuals in India.

PROBLEMS OF A MOTION PICTURE RESEARCH LIBRARY*

H. G. PERCEY**

Summary.—*The organization and equipment of the research department at Paramount Studios are described. The difference in the problems of research on historical and modern photoplays is explained, with specific examples from current pictures.*

In the days when Jesse Lasky and Cecil B. DeMille operated a little motion picture studio on Vine Street in Hollywood, there was employed as a reader in the Story Department an actress who had "trod the boards" from Minnesota to Louisiana and from New York to California. Because of her wide experience and excellent memory, the production staff formed the habit of asking her what the butler had worn in this play, or whether the desk in that one was Governor Winthrop, or Mission. One day, as the company flourished, they decided to have their stories reviewed in New York, and this actress, Elizabeth McGaffey, persuaded them to give her a dictionary, the *National Geographic Magazine*, and a public library card, and allow her to start a research department. This eventful happening took place in 1914.

It grew slowly at first, with an occasional magazine added: the *London News*, because of the War; the *Architectural Record*, for the Art Department; and a few books for each picture. In fact, for many years the chief growth of the department was in connection with important pictures. No additions to the department have excelled the splendid architectural material on Spain purchased for *Spanish Dancer*. For *Ten Commandments* were purchased the *La Sainte Bible* with the Tissot illustrations, the *Encyclopaedia of Religion and Ethics, and many commentaries on the Bible;* for *Old Ironsides*, fine boat books; while for *The Patriot*, some rare Russian historical material was added, including the two-volume set published to commemorate the coronation of Tsar Nicholas II.

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Paramount Productions, Inc., Hollywood, Calif.

Today, there are 8100 books and bound magazines, and a picture file greater than that of the Los Angeles Public Library. The collection, though still built ostensibly around productions, has been augmented by a great many standard reference sets of encyclopedias, the *Yale University Pageant of America, Peoples of All Nations, Countries of the World, Lands and Peoples, Manners and Customs of Mankind, History of the Nations,* and the *Smithsonian Institution Scientific Series.* The library subscribes also for the more important magazine indexes, thus making available for use a large stock of bound and current periodicals, including *Asia, Architectural Forum, Arts and Decoration, House and Garden, Travel,* many foreign weeklies, and various news magazines.

Although the work of the department was at first restricted to little more than finding out what had been used for the stage play, or what the sheriff's badge of the eighteen-eighties was like for a "western," gradually not only the production units, but all the departments, learned to depend upon research to help solve their problems. Regardless of our over-zealous publicity departments' stories, the librarians have never claimed infallibility, nor deserved it. Given enough time, and enough money, they can usually find satisfactory material; but when a director sends in an order from a set, with the breathless messenger hanging over our shoulders while we try to find a picture of a wedding ring used in Spain in the seventeenth century, the battle is lost. No other department in the studio is used by so many persons, and for so many purposes. Bing Crosby wishes to pick out the moustache he will wear in *Mississippi.* The Art Director wants to see the interior of an old English stable for *Peter Ibbetson;* for the latter picture the Costume Designer must to see the hat worn by a little boy with an Eton suit in 1819. The Censorship Department has been warned that the life of a character in a forthcoming picture resembles that of some noted diplomat, so biographical material must be found. The interior view of a church for slaves is wanted by King Vidor for *So Red the Rose.* The Drapery Department needs yacht flags and insignia for *The Big Broadcast* of 1935. How to address an informal note to an English countess is the problem of the Foreign Department, while the Legal Department wishes to check upon a play bearing a title similar to one recently purchased by the company. A letter received by the Fan Mail Department asks the nationality of the adventuress in *Lives of a Bengal Lancer;* and some one else wishes the name of the musical instrument used to charm the snake. The unit business manager wants the name of a Turkish technical advisor for *The Last Outpost.* A real spider spinning a real web is wanted by the Special Effects Department; and an engineer from the Sound Department asks whether it is true that a waterspout can be broken by shooting a cannon into it.

Our greatest problems, and the most interesting, arise in making historical pictures. An excellent example is *The Crusades.* The preliminary work was done on it a whole year ago, when histories of the Third Crusade, and biographies of Richard the Lion Hearted were located. In July, Harold Lamb, whose scholarly but readable books upon the subject have made him an authority, was assigned to write an original story. Our work with him proved to be of great length, but fascinating, relating to the costumes of kings and queens, lords and ladies, minstrels and priests; army life, military tactics, and battle cries; the manner of saluting an officer, and paying homage to a king; marriage customs of the twelfth century in France, and religious customs among the Saracens. How much of Windsor Castle was built at that time, and how was it furnished? Not only Mr. Lamb, but, in his wake, art director, set dresser, sketch artists, and technicians, all plied us with questions. One point alone may serve to illustrate what pains are taken to be exactly correct, and yet how difficult it often is to find information upon what seems to be rather simple. There is a scene in the script in which Richard visits the smithy to see how his new sword is progressing, and himself strikes a few blows with the hammer. While he is thus engaged, a messenger summons him back to the castle, to greet Philip Augustus of France, an unexpected guest. The same evening the smith delivers the finished sword. Could a sword be tempered, polished, and finished so quickly? First we searched the material on arms and armor; then the books on the arts and crafts of the Middle Ages, narratives of the time, and even historical novels and children's stories. In the magazine indexes we found countless articles on the history and manufacture of swords, but none that answered the question. We tried the Huntington Library, and the University libraries; finally, even the Library of Congress, but their great resources contained no such data. Through an army officer, we found the name of the firm that had made the last issue of cavalry sabers, but even they could not tell us how long it had taken them, let alone how long it might have taken an armorer of the twelfth century. The Chief of Ordnance sent us the government specifications for swords, which proved very amusing to the DeMille unit, but of no help. Just as we had about given up hope, two articles appeared in magazines regarding the work of Kenneth Lynch, a metal craftsman, with a forge in Long Island City. A letter to him brought the information that he had made some of the swords for *The Crusades*, and that he believed that at that time it would have taken three men one day's work to make a sword.

The costume problem is a grave one, and is still quite unrecognized by many directors. We have all the great authorities, including Racinet, Planche, Hottenroth, Rosenberg, and Giafferri; uniform regulations, books on coiffures, fashion magazines, and countless others; but the costume must please not only the designer but the director and the star. The designer may not want the Spanish costume of the province in which the story is written, but one worn in Argentina, or depicted by Sargent in El Jaleo. The director may know that the Alaskan Indians wear something closely resembling a "Mother-Hubbard," but one can not blame him for not putting such an outfit upon a supposedly languorous lady. A masculine star would not wear knee breeches in a Revolutionary War picture, because he thought them unbecoming.

Competent technical advisors are indispensable in connection with pictures, the locale of which is supposed to be in a foreign country or which is concerned with some special subject, such as the army or navy, aviation or engineering. Occasionally, one will misrepresent his capabilities, but there are so many nationalities represented on the payroll of any studio that it is not difficult to find such information. There are countless questions of customs and procedure that are not answered in books; infinite details of costume, which make all the difference between right and wrong to the natives of a country, but would never be noticed by Americans. For every good technical person employed, our knowledge of the country is enriched, but unfortunately, we receive all the criticisms of the incompetent ones.

On the average modern American picture, the work is seldom exhaustive. For *Stolen Harmony*, we sent for city or state police uniforms and equipment from four states, only to find there was hardly a glimpse of them left when the picture was finished. Prison pictures worry us a little, because with the new prison reforms prevalent in so many of the states, we do not always find the stripes and chains that are usually associated with the punishment of criminals.

A part of the work that we find particularly enjoyable is that done with some of the musical composers. For instance, before Ralph Rainger began composing the music for *Rose of the Rancho* he spent hours looking at pictures and reading books upon the customs of early California—life on the big ranches, the fiestas, the dances—everything but the music.

There is no end to the work that can be done, nor to the material that can be used in a research department. We once made a survey of the employees to find out where we could get specialized information quickly. The employees have been particularly valuable in connection with European War stories, because practically every branch of foreign service is represented, and also for small amounts of translation that are often needed quickly, such as a German sign in a train, or a Spanish letter. None of the research departments has the equipment to do scientific research, but that is a goal toward which we can work.

There is a nation-wide movement, now well organized, that is going to have a decided effect upon motion pictures, and by the very nature of it, upon the growth of research departments in the industry—Motion Picture Appreciation—which is being studied in the public schools in connection with the English classes. When we realize that there are no fewer than thirty million children and adolescents in the schools of the United States, it must be evident that teaching them not only discrimination but criticism as well, is bound to influence a number of factors that today many persons feel are of little consequence. One of the English teachers in a Junior High School told us that surveys made a year ago and again this spring had shown a surprisingly great increase in the attendance at recommended pictures. The Women's Clubs, the Parent-Teachers Associations, the Theater Managers, the Public Libraries, are all doing their best to help. Pamphlets are issued on a few of the specially recommended films such as *David Copperfield*, one hundred and twenty-four thousand of which are being circulated. The Public Libraries give out book-marks referring to these and some of the historical pictures, suggesting other books on the same or similar subjects, readable histories, biographies, and novels. All this leads to an intelligent demand for better entertainment, more accurately presented; and perhaps the research departments will soon come into their own.

DISCUSSION

MR. CRABTREE: Is your equipment restricted to books, or do you have file records of photographs, clippings, *etc?* Also, do you have a directory of persons in Hollywood who can tell you what is worn in France or Ireland or other countries? It would seem that such a person would be able to put you right about costumes in much shorter time than by reading a book.

MISS PERCEY: That is true, and we do try to get them; but we must investigate them very carefully, because very often they have not been abroad for a long time—sometimes years—and when they go to the wardrobe department to pick out a policeman's uniform, for example, the one they pick out is hopelessly out of date.

Yes, we have a directory of research experts. But, as in everything else, it is always something that we do not have that is asked of us. We have also a very large clipping and photograph file. We have practically no scientific books. The library has been built around the motion pictures we have made, and not around the future needs of the staff or the studio. In time to come, perhaps, we shall have at least the important scientific encyclopedias and similar material, which should be owned by the studio and not by individuals in the sound or other departments.

I was very much interested in the films taken with polarized light, because one of our difficulties is that of supplying photographs to be used in pictures as backings outside windows. When filming a scene in France, for instance, a photograph typifying French scenery may be required, and our great trouble is that often we have no such photographs, but have, instead, very good rotogravure prints. With the polarizing filters, it will be possible to enlarge the prints satisfactorily, I believe.

MR. CRABTREE: Yes, we get as good reproductions from mat prints as from glossy prints.

MISS PERCEY: That is very interesting. It will help to solve some of our problems.

PRESIDENT TASKER: That is another example of how the Society mutually assists the various persons in the industry.

MR. CRABTREE: It supports Professor Morkovin's statement that the more each man knows of the other man's problems, the more valuable he is to the industry. A specialist these days must be a jack of all trades, with an extra knowledge of his particular subject. Miss Percey, how many persons are employed in your department?

MISS PERCEY: We have only five in the Research Library at Paramount Studio. One of our exchange men came to the studio not long ago and looked around almost with disgust. Having read the accounts of the enormous research staff that Mr. DeMille used on *Cleopatra* and *The Crusades*, he was horrified when he saw my rather limited library, and only five of us. He said, "I thought you had at least 300 persons employed."

THE HISTORICAL MOTION PICTURE EXHIBIT AT THE LOS ANGELES MUSEUM*

E. THEISEN **

Summary.—*The development of the historical motion picture exhibit at the Los Angeles Museum sponsored by the Society is described, from 1930 when the first gallery was opened. The various contributions of the pioneers represented in the exhibit are discussed, and a description of the various accessions and the policies of the Museum in displaying these collections is given.*

The historical exhibit of motion picture relics at the Los Angeles Museum is being brought together so that the relics may not become scattered or lost. The records and apparatus of many of the arts, and even many of the traditions incidental to their development have been lost because of a lack of interest in preserving the material or putting it into suitable and safe depositories. Even now, scarcely more than forty years since the motion picture began, many of the records and much of the mechanical paraphernalia have been lost. However, the Society of Motion Picture Engineers and the Los Angeles Museum, in collaboration, have sponsored the activity of preserving as many relics and memorabilia of the motion picture as possible.

Because many of the motion picture pioneers did not realize the importance of their researches, they did not preserve their devices intact, but, instead, removed sprockets, gears, or parts of the devices for use in further experimentation, with the result that the original equipment was gradually dismantled. Time after time, in the search for the original equipment, such was found to be the case. Fires, the death of the pioneer, and lack of funds are other reasons for the destruction and scattering of the records.

Realizing all this, the idea of a motion picture museum was crystal-

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Los Angeles Museum, Los Angeles, Calif.

lized. The Motion Picture Division of the Los Angeles Museum was organized in January, 1930, with Earl Theisen Honorary Curator. On December 10, 1931, the Board of Governors of the Society of Motion Picture Engineers appointed a Committee known as the Museum Committee, whose duty it was to aid in bringing together the relics of the motion picture. The Los Angeles Museum was chosen as a depository.

The initial exhibit in the Museum at that time was a collection of approximately 1200 specimens of film, representing the entire history of the motion picture. The collection included actual clippings from original films of pioneers and from notable photoplays from year to year, color, sound, and the various processes, each being represented by separate specimens bound between glass plates for preservation, and accompanying each specimen was a historical notation.

FIG. 1. S. M. P. E. motion picture exhibit, Los Angeles Museum.

In the collection, which is still on display, may be seen raw stock made by Eastman in 1890, and motion pictures made by W. K. L. Dickson for Edison in 1889. There are numerous examples of the earliest films to be projected upon screens, including those of Woodville Latham, the Lumière Brothers, the Biograph, and others. Specimens of hand-colored motion pictures made in 1898 may also be seen. There are also specimens of stop-motion, and motion pictures by miniatures, of the same period.

There is one specimen on display that corresponds to the main title of current pictures. It is a film in which are two frames of title bearing the statement, "Copyrighted by T. A. Edison, 1897." It was inserted five feet from the start of the film so as not to be torn away as a result of the practice at that time of removing the short sections of the film that were damaged by the starting of the projector. In the collection are also specimens of such noted pictures as *The Great Train Robbery*, *The Birth of a Nation*, and others. There are samples of sound-films made by Ernst Ruhmer as early as 1904, and animated cartoons made by J. Stewart Blackton as early as 1906.

The specimens are displayed by means of backlighting in an open-air case arrangement, so that the film specimens will not be heated above 70 degrees. This collection of motion picture film specimens was first begun by Earl Theisen in 1924, and includes samples obtained from all over the world.

Since 1930, when the Motion Picture Museum idea was crystallized, there has been constant activity in assembling the available relics. The Los Angeles Museum has furnished assistance and display facilities, while the sponsorship of the Society of Motion Picture Engineers, under the guidance of the Historical and Museum Committee, has aided considerably in bringing together the material.

Many notable private collections have been deposited with the Los Angeles Museum, and many records of the motion picture pioneers are represented. On display may be seen a model of "The Black Maria," the first Edison studio. This model was made from specifications furnished by W. K. L. Dickson, who made the original studio for Edison in the early 1890's. Besides this model there are other models showing a present-day sound stage with all its appurtenances. There is also a model showing how a glass matte process "shot" is photographed. Plans have been promulgated for adding to the miniature models in this display as and when they can be made.

Particular attention is being given toward bringing together the mechanical equipment. Projectors and cameras made by a number of pioneers have already been acquired, and have been treated to prevent corrosion and destruction before placing on display. This equipment, after being received at the Museum, is carefully cleaned, the rust is removed, and it is so treated as to prevent the formation of new rust.

Many archives have also been gathered both for preservation and display. The catalogs issued by the Biograph Company showing photographs from the first Biograph films have been acquired from the collection of George E. Van Guysling. Mr. Van Guysling, who was Manager of the Biograph Company during the years 1904 to 1907, saved many of the records of the Biograph Company. For the most part these have been placed with the Los Angeles Museum; some have been put into display cases, while the other material has been placed in the Museum storeroom for safe-keeping. A storeroom of about 3000 square feet has been set aside for this purpose.

Mr. J. Stuart Blackton has made available material from the old Vitagraph Company. In the Blackton collection may be seen, among other things, the drawings from which was made the Vitagraph trademark. Mr. Blackton also supplied a Biograph mutoscope "peep show," of 1908. In this mutoscope may be seen a complete picture showing the members of the Patents Company. One-half of the men shown in the picture have since died. The motion picture is not upon film, but upon the mutoscope cards which flipped past the line of vision and thus integrated the progressive motion of the successive photographs upon the cards.

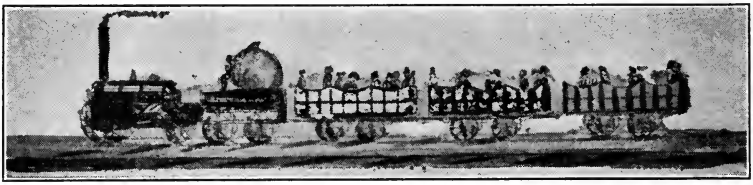

FIG. 2. Old slide of about 1831–32, on display in the S. M. P. E. exhibit. Only a small portion could be projected at a time. The slide was painted in panorama, so that motion of the train would be simulated as the slide was passed through the lantern. Candles were used in the magic lantern for illumination.

Other pioneers have supplied photographs, hand-bills, and other memorabilia from the Kalem, Lubin, Essanay, Selig, and, in fact, all the more widely known early motion picture companies. Much of this material is in the form of hand-bills, as in the case of a collection of Edison programs during the period of 1909 to 1911 furnished by Herbert Prior, an Edison leading man at that time. These hand-bills bear descriptions of the pictures, photographs, and, in later hand-bills, listings of the casts.

Records on display at the Museum indicate that the motion picture players first began to receive publicity in 1910. A copy of the *Sunday Post Dispatch* of St. Louis carried a feature article on May 20, 1910, announcing for the first time "that the IMP Girl is really Florence Lawrence." This, according to available records, was the first publicity given to a motion picture player, and was brought about through the enterprise of Carl Laemmle, for whom Florence Lawrence was working at the time.

The *Motion Picture Story Magazine*, which was first published in February, 1911, by J. Stuart Blackton as the Patent Company's publication, carried stories about the players. One of the early pictures in which Edison gave credit to a cast was a 700-ft. picture entitled *The International Heart-Breaker*, released on December 11, 1911. Examples of all this "star" publicity may be seen on display in the Museum exhibit.

The Museum also has on display, from the George E. Van Guysling collection, hand-bills from motion pictures made in Los Angeles in 1906. One hand-bill issued by the Biograph Company from their Los Angeles office, 2623 Pico Street, dated June 17, 1906, announces a picture entitled *A Daring Hold-Up in Southern California.* An earlier picture had been made on June 10, 1906. There is also on display an announcement from the *Billboard Magazine* of that time, of the opening at Los Angeles of a branch of the American Biograph Co. As indicated by the Los Angeles City Directory, the Biograph Company remained in Los Angeles continually from that date until the dissolution of the company. There is a popular tradition that the first motion pictures were made in Los Angeles by Colonel W. N. Selig in 1908. David Horsley is credited with making the first pictures in Hollywood in October, 1911.

These hand-bills, along with suitable photographs, are displayed in swinging frames permitting the visitors to the museum to study the exhibit closely. Also in the swinging frames are many patent papers and other documents. Upon the walls are framed and autographed pictures of many of the motion picture pioneers, including Edison, Eastman, and others. Framed nickelodeon posters hang upon the wall.

Upon display in the gallery is an attempt to show how the idea of motion pictures began more than 250 centuries ago and evolved up to the present time. A photograph is shown, supplied by Will Day of London, of a boar having two distinct sets of legs, the original drawing of which, upon the wall of a cave at Altmira, Spain, dates back to approximately 25,000 B.C. The drawing was evidently an attempt by the artists of that time to represent motion pictorially. Preserved in the Museum files are records of many attempts to produce motion pictures before photography was available, an example of which was the magic lantern. On display are magic lanterns exploying either candles or kerosene, and many beautifully hand-painted slides, arranged in narrative sequence with the idea of telling a story. For instance, the travel lecture, *Through the Holy Land,* depicts in succession the various interesting sights of the Holy Land, intended to be accompanied by suitable explanatory discussion. As an example of the "story slides," there is *The Orphan's Dream,* in which is depicted in a series of three slides the story of the little orphan going to Heaven and seeing the angels. The first slide, known as the "foundation slide," showed the orphan asleep upon a couch; the second slide was superimposed in the upper right-hand corner and gradually slid into view upon the screen, thus introducing the idea of the angels appearing to the orphan.

Besides the historical material upon display, material has been designed to explain the current motion picture processes, such as the making of an animated cartoon, the coloring of motion pictures, the lighting technics, *etc.* In these displays, wherever possible, actual examples of the successive steps of the processes are shown, along with suitable labels.

The Historical and Museum Committee and the Los Angeles Museum are particularly interested in preserving the history of the motion picture as it unfolds. With this purpose, various companies and leaders of the cinema are encouraged to send literature, paraphernalia, and other items that portray evolutionary progress. A number of magazines send complimentary subscriptions so that a complete file of current events is preserved.

At this time it is fitting that a plea be made for further accessions and for the coöperation of those who may have in their possession any historical motion picture material. Persons having such material owe posterity a duty. Motion picture relics must be preserved, and since there is little commerical value attached to the relics, it follows that this material should be deposited with the Motion Picture Museum. Credit is always given to the donors upon labels describing the exhibits. In certain instances where it is inadvisable to make the material an outright gift to the Museum, recall privileges may be granted.

THE MOTION PICTURE COLLECTION AT THE NATIONAL MUSEUM*

A. J. OLMSTEAD**

Summary.—*The Smithsonian Institution was created in 1846 by act of Congress according to the terms of the will of James Smithson, of England, who bequeathed his property to the U. S. Government for the purpose of founding at Washington an establishment for increasing and diffusing knowledge among men, and to be known as the Smithsonian Institution. The Section of Photography is a part of the Division of Graphic Arts. It constitutes in its exhibits a history of photography, both still and motion, as represented by 12,180 specimens. The present paper describes some of these exhibits in relation to their historical aspects.*

Recently I was advised that the Board of Governors of the Society had sanctioned the Smithsonian Institution as a depository of motion picture material, thus authorizing in the East a depository for the exhibition and display of such equipment. Museums grow slowly and exhibit and care for what has passed into history. We speak of material over 50 years old as being of museum age, under which rule motion picture apparatus is just approaching maturity, as I believe the beginnings of the motion picture industry were some 40 years ago. However, early machines, methods, and processes are rapidly passing, and no time should be wasted in collecting the material and placing it where it will be cared for and be safe. Of all museums, national, state, or city, the national is on a most enduring foundation. The section of photography, covering both still and motion pictures, is some sixty years old; and here a tribute should be paid to its founder, Thomas W. Smillie, who had the wisdom to make the beginning and whose chief interest it was during the forty-eight years in which he served the Institution.

It is my purpose to review briefly the motion picture material now in the collection, and to invite you to inspect it. Toys embodying the principle of persistence of vision as a factor in creating an illusion of motion date back to 1830. We have a combination toy *zoëtrope*

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** Smithsonian Institution, Washington, D. C.

dated 1876, from the U. S. Patent Office, the inventor of which states that it can be used as a paper collar-box after the termination of its period of usefulness as a toy. Other zoëtropes or "Whirligigs of Life" are shown, some employing mirrors and some lenses in their construction. The *periphantoscope* whirls before a mirror, thus differing in construction from the zoëtropes in that the reflection is viewed through slotted openings, a whole library of carefully drawn disks being provided to afford a variety of entertainment. The *phantoscope* provides a semblance of motion by allowing a series of prints bound tightly together at one edge to flip successively under the thumb at the opposite edge. These are some of the devices of the premovie days, mainly for the purpose of providing amusement for children and adults.

The Eadweard Muybridge collection is very complete. Muybridge began his historic experiments in 1872 in an effort to settle a dispute as to whether a trotting horse had all four feet off the ground at any part of its stride. His work and his photographs of the horse, taken with twenty-four cameras, form a historic episode in the art, and proved this to be true. Following his work in California, Muybridge was given a grant of forty thousand dollars by the University of Pennsylvania to carry further his study of human and animal motion, the culmination of which work embodied the publication of some eight hundred photogravure plates of a wide variety of subjects, for which he received world-wide recognition. The work was all done with dry plates, exposed serially in a battery of cameras—not a single camera and single point of view, as we now take motion pictures. The *zoöpraxiscope* was Muybridge's instrument for projecting the pictures.

In 1887 Wallace Gould Levison, a member of the Brooklyn Academy of Science, constructed a camera, included in the collection of the Smithsonian, that would expose twelve plates in less than a second. These plates were placed upon the periphery of a drum and exposed by an electrically operated shutter. This camera recorded motion from one point of view, thus differing in principle and practice from Muybridge's multiple-camera method.

Film came upon the market about 1888, and was a big aid in the solution of the movie camera and projector problems. Of Edison's material the most important in the collection is a projection *kinetoscope*, the lamp house of which contains a lime light: electricity was not then so available as now. There are also two cameras and a light-testing machine accredited to Edison; and a synchronizer, dated 1908, in which an effort was made to synchronize an Edison talking machine with a motion picture film. The machine was operated by a battery, and to keep the picture and speech together, the operator kept the green light burning, the red being an indication of "out of time." It has been said that with the present means of sound reproduction and amplication, this machine would give excellent results with old film and records. The great difficulty at the time was not that of keeping the sound and picture together, but that the sound was weak and the needle scratched badly.

One of the first projectors to be used commercially, the *eidoloscope*, was invented by Woodville Latham, and was used in April, 1895, to give public exhibitions in New York, N. Y. It was probably the third machine of its kind that was constructed, and was used by LeRoy Latham, a son of Woodville Latham, to give exhibitions at Norfolk, Newport News, and Richmond. A later machine, patented in 1902, maintained the loop and included an intermittent movement with an improved shutter. The instrument stands in a case in the Museum by itself, and was shown at the sesquicentennial exposition at Philadelphia.

In connection with the eidoloscope I well remember the first visit of Eugene A. Lauste to the motion picture exhibit. He greeted this machine with affection and much feeling, saying that he did not know that one existed, and that he had helped to build the machine as well as design it.

The Jenkins material at present fills one section of a wall case. Fifteen years ago a small part of this collection formed the beginning of the Museum's exhibit of motion picture apparatus. The Muybridge material was added later.

The Jenkins exhibit is most complete: it includes equipment dating from Jenkins' experiments and processes to the final aerial mapping camera, one of his last jobs. The list is a long one and I shall only mention the items in a general way: early motion picture cameras and projectors; later equipment for radio transmission of photographs; television and motion picture equipment; high-speed motion picture cameras for analysis of motion; apparatus for transmitting weather maps by radio to ships at sea; and, finally, the aerial mapping camera already mentioned.

Edward Amet, of Waukegan, Ill., did some early work on projection. We have three of his models: (*1*) a demonstration model to prove that a motion picture could be taken and projected; (*2*) one made in 1894–95, of which some 500 were made and sold; (*3*) one made for the market in 1900, employing a claw.

Of the work of Marvin and Casler we have three cameras and one projector. The machines are large and cumbersome; the camera was driven by a 2-hp. motor, and the film was $2^3/_4$ inches wide, without perforations. It was exposed at the rate of forty a second. The camera that they constructed worked, and did not infringe existing patents. The design was largely due to the genius of Casler. The prints were first shown in a peep-hole machine known as the *mutoscope*, and later positives were projected with a machine known as the *biograph*. The work of these two men resulted in the formation in 1896, of the great Biograph Company that made motion picture history for the next 20 years, invading England and France and constructing studios and laboratories.

Standing at the corner of the exhibit, and in actual operation, we have one of the mutoscopes mentioned above, which was shown by the U. S. Post Office Department at the St. Louis Exposition in 1904.

Eberhardt Schneider is represented by two early printers, three perforators, four film polishers and rewinds, five projector heads and five cameras, all of his invention and manufacture.

Most important and of great interest in this collection is a frame of film specimens dating from 1895.

Recently there have been acquired from the Bell Telephone Laboratories a collection of fifty-nine specimens of the early work of Eugene A. Lauste, of whose contributions to the modern sound picture art too much can not be said. Lauste's work began in the eighties: in 1889 he was with Edison, and later with Woodville Latham (1894), designing and building the eidoloscope, used for public performances in 1895. He was first to record sound and scene upon the same film, his English patent being dated August, 1906. Lacking vacuum tube amplification, he was unable to operate his loud speakers with satisfactory volume. His work in recording sound was far in advance of the science of reproduction.

To mention a few of the more important models: 1908–9, sound reproducer; 1910–11, camera and projector for sound and scene; 1911–12, sound recorder; 1912–13, sound and scene projector. Added to this material later was a most valuable collection of photographs and manuscripts, carefully arranged by Mr. Lauste over a period of years, descriptive of his work and that of many of his contemporaries in the early days of motion picture development. Mr. Lauste had the pleasure of seeing his exhibit arranged upon the shelves of the Smithsonian a few short weeks before his death on June 26, 1935.

Last, but not least, in October, 1923, this Society—the Society of Motion Picture Engineers—presented the Institution with a historical collection, consisting of some 15 specimens of film strips and screen-plates of which I shall mention a few: McDonough-Joly screen-plate; Fenske Aurora screen-plate; Thames plates; Kelley line-screen; Krayn screen; Omnicolor plate; Ives chromoscope slides; and Biograph, Brewster, Prizma, and Technicolor film strips.

In preparing this paper I have discovered the list of the historical motion picture material now in the collection is a sizable one, and, in conclusion, will as a summary mention the names of some the inventors whose work is now represented: Muybridge, Levison, Edison, Latham, Jenkins, Amet, Marvin and Casler, Schneider, and Lauste—all names that appear large in motion picture history.

THE INTERRELATION OF TECHNICAL AND DRAMATIC DEVICES OF MOTION PICTURES*

B. V. MORKOVIN**

Summary.—*The dramatic technic of motion pictures is determined by the cinema mechanics and by the way the actual world is shaped through the medium of lens and microphone. The technician must be guided in his work by an understanding of the dramatic purposes and meanings of the devices used and by a knowledge of the fundamentals of cinematic dramaturgy. Some of the requisites for attaining a harmonious blend of all the cinematic powers and possibilities, and the differences between mere stage productions and motion picture productions are pointed out.*

Dramatic art, whether it be literary, stage, or screen drama, works upon the emotions of the readers and audiences by twofold processes, opposed to each other, yet harmoniously balanced:

One takes them away from the vexations of their actual life into the realm of make-believe. It fascinates by imaginary transformation of life, and transports by the spark of unreality.

The other process makes believable the impossible and the strange. By an illusion of life-likeness it stirs the interest, arouses sympathetic emotions, and plays upon the keyboard of the past experience of the readers and spectators. Drama gives the excitement and thrill of first-hand experience without making the reader or spectator pay the price for his experience.

The form of drama most expressive in its means, most adequate for conveying the complex experience of our dynamic age, is the cinematic drama, the motion picture. Unprecedented in history by any other form of artistic expression, cinematic means, since their inception a little more than half a century ago, have been continuously and cumulatively enriched by the work of national and international geniuses of science and technic. The fields directly or indirectly related to the cinema have been enhancing the powers of cinematic expression: sound, light, electricity, chemistry, all branches of photography, radio, television, *etc.* This scientific and technical contribu-

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** University of Southern California, Los Angeles, and Walt Disney Studios, Hollywood, Calif.

tion keeps perfecting the cinematic tools and their ability to capture and reproduce human experience with precision, sensitiveness, and vigor. At the same time, the cinema has benefited from the growing richness and finesse of all the arts that constitute its ingredients and contributors: literature, legitimate theater stagecraft, painting, sculpture, architecture, music, and ballet.

Not unlike modern witchcraft, the cinema creates in the mind of the spectator an illusion of living through the life experiences of characters. It achieves this by means of sympathy with or for characters and their vicissitudes, and by empathy, or unconscious repetition in the spectator's muscles and body of the movements and actions of characters.

In order to produce this hypnotic illusion, cinema has mastered its material and tools and made them malleable, and has learned to organize its material into a variety of stimuli working upon the human nerves of eyes and ears and indirectly upon the nerves of the other senses. The material for the visual stimuli is provided by the actors, their bodies, feelings, and thoughts; by the costumes, make-up, furniture, settings, and other props of all epochs and descriptions; by composition of lines and masses, clarified and reënforced by camera angles and distances, and by distribution of light and shadows: the material for aural stimuli is provided by sounds, noises, dialog, and music. All these stimuli are organized emotionally into peculiar, dramatic patterns. The cinematic stimuli, as the Greek *κινεμα* indicates, work essentially by means of movements, large and small, from the mere drooping of the eyelids to spectacular battles and chases and the play of emotions behind them as the motivating forces. The dramatic expressiveness and powers of the cinema are increased by the technical progress, the perfection of technical equipment, camera, lighting, optical printer, processes, sound equipment, color, *etc.*

The scenario writer and the director, who translate the story into cinematic terms, have to learn to think cinematically, to become cinema conscious. Like a good musician who hears the music while reading the notes, the director while reading the story, or its adaptation, must visualize it in actions, movements, and sounds with dialog added for punch and clarity. Technical devices of the cinema and their effects play the same role for the scenario writer and director as do words for the writer of fiction. The richer and more expressive the vocabulary of words, idioms, metaphors, and associations commanded by a fiction writer, the greater the facility and freedom of imagination in his writing. Likewise with the scenario writer and the director; in order to express effectively the dramatic situations and the mental states of the characters, they must have at their finger tips a large "catalog" of dramatic effects and all the psychological capabilities of numerous technical devices of camera, light, and sound, and must know also when and how to use them. If they are not skilled in the cinematic technic and are not cinema conscious, they will depend entirely upon the technicians for their cinematic resources. They will not create an imaginative cinematic drama; they will merely transpose the story scene by scene into terms of camera and microphone with the customary dialog. They will use literary and stage technic instead of the cinematic technic of movement and interaction of characters.

In translating stories into motion pictures, scenario writers and directors should adhere to rules governing their construction into scenes and sequences that are in accordance with the essential technical nature of cinema. Cinematic devices produced by the camera and the microphone or by cutting must not be strung together mechanically. The attempt to do so by directors who are not trained cinematically is equivalent to translating from one language into another without possessing a knowledge of grammar and syntax and trying to put together in a haphazard way the words looked up in the dictionary.

The eyes and ears unconsciously register and coördinate in the brain the different aspects of visual and aural experience. Being parts of one head, eyes and ears blend their experiences automatically, each reënforcing the other. The cinematic eye—the lens, and cinematic ear—the microphone, do not proceed automatically to register and coördinate the material they record. The brains behind them, the cinematographer, the sound engineer, and the director, make a great and deliberate effort to weld different visual and aural effects and orchestrate them effectively, as it were, into a technical and dramatic unity.

The "filmic" world by no means is a reproduction of the real world. It is artificial and technical, through and through. It has its own space and time; in conveying moods and delineating characters and events, it uses its short-hand language of suggestions, contrasts, comparisons, and symbolism. Working with prearranged illusions, it is sometimes more realistic and vivid than reality itself. A forceful film can be produced only by a smoothly flowing continuity built in a dramatically crescendo. For that purpose the director and editor should know how to guide the spectator's thoughts and feelings into a total dramatically unified impression; how to tell the story skillfully in pictures and sound, with well timed atmospheric effects accomplished by the various technical devices. The attention of the spectator is guided and directed by the distribution of light, converging lines and emphasis by contrast, by close-ups, by sound, inanimate objects, dramatic clash, by increased or decreased tempo. A cinematically trained director having all the cinematic resources at the tip of his finger, effectively organizes them and builds his drama as an engineer with a thorough knowledge of his materials, combining them according to the purpose he wishes to achieve. He keeps the spectator's emotions at close grips with the unfolding cinematic drama, stirring them profoundly at the climax, and sending the spectator home after settling the main issues of the hero's predicament.

The progress achieved by the technicians and engineers contributes immensely to the dramatic progress and effectiveness of motion pictures. The expressive power at the disposal of the writers and directors depends upon the precision, sensitiveness, flexibility, and efficiency of the equipment, and upon the ability to control the conditions under which the equipment is used. The work is accomplished by minutely dividing the labor of the technical workers and the functions of the contrivances and instruments used. Each of these instruments and devices produces different effects. The minute specialization of the work of each technician and each instrument increases the difficulty of adjusting and harmonizing each phase of the work with all the others.

The integration of all these effects into a practical unity resembles, in a way, the solving of a jigsaw puzzle. And yet the success of a picture and its ability to gain and hold the spectator's attention spontaneously are not immediately due to the splendid technical devices, but to the fact that the picture creates an impression of having been made out of one piece and the single effects entirely submerged by the whole.

Because of the need of harmoniously blending all the technical devices to produce a unified dramatic effect, it is necessary that:

(*1*) The technicians have a fundamental knowledge of other technical media—

camera, sound, light, composition, set construction, *etc.*, since these are interdependent and intertwined.

(*2*) The work of the technicians, in order to be in harmony with the aims of the director, must be guided by an understanding of the dramatic purposes and meanings of the devices they use and by the knowledge of fundamentals of the dramatic structure.

The unprecedented progress of the American motion picture industry has secured its world leading position. If this position is to be maintained, it is not sufficient to organize the progress in each of its fields, technical and dramatic, separately; both fields should be more closely interrelated, and the progress in technical machinery and devices should be utilized more fully for psychological and dramatic effects. This would at the same time eliminate a good deal of the production waste caused by the hit-and-miss methods. For this purpose are required:

(*1*) Research into the interrelation of the technical, psychological, and dramatic aspects of cinematic devices.

(*2*) Research into the laws and technic of blending the effects of the various optical and auditory devices into the new values and dramatic possibilities arising from their combination.

(*3*) Opportunity for technicians and engineers to study the fundamentals of other and adjacent technics, cinematic dramaturgy, and the dramatic and psychological effects of the various technical devices.

(*4*) To provide facilities for the dramatic workers of the industry, scenario writers, directors, editors, and others to study the fundamentals of motion picture technic and to experiment with it.

The industry must eliminate the haphazard methods of hit and miss in organizing its production. The nature of the cinema as an interrelation between the dramatic and the technical aspects should be thoroughly understood and scientifically and experimentally elucidated. When that is done, the difference between the motion picture industry and the sausage or the automobile industry will be clearly seen. New untouched and unlimited potentialities of motion picture science, technic, and art will be opened. Then industry will have the technical and dramatic super-experts, who will understand the laws of blending harmoniously all the cinematic media, recognize the technical and dramatic powers and possibilities of the cinema, and how to use them in every changing situation. This research and study should be organized by the studios for their members with the coöperation of the various educational, engineering, scientific, and dramatic bodies versed in the subject.

THE USE OF MOTION PICTURES IN HUMAN POWER MEASUREMENT*

J. M. ALBERT**

***Summary.**—A brief description of the application of motion pictures to the study of the motions of operatives in factories, etc. Eight-mm. film is used, and means are provided for studying and analyzing the motions either at various speeds of projection or frame by frame.*

The object of this paper is to acquaint the motion picture engineer with some of the problems that confront the industrial engineer, and how the development of motion picture equipment for use in such work is assisting to solve these problems.

All items of cost must be measured by some recognized unit, and once the measuring unit is established, its evaluation in terms of dollars is simple. Therefore, if the work of the industrial engineer is to be accurate, all items of cost *including* labor cost must be reduced to a unit-of-measurement terminology.

Until such a unit was developed by Chas. E. Bedaux some years ago, industry had no uniform and accurate scale by which to measure the expenditure of human effort. Men were hired by the year, the month, day, hour, or piece for a certain sum, and their efforts were measured by what they produced in terms of pounds, feet, gallons, *etc.* As a historical record of cost this method enabled the business man to know whether during the past year he had made a profit or a loss, but it did not tell him why, nor did it provide him with any means of controlling his expenditures.

In order to control costs it is necessary to know, not only the actual costs, but, far more important, what the costs should have been. Having established standards of production for each operation in the plant, the setting of standard costs is quite simple. The Bedaux Unit, or *B*, is the unit for measuring human effort. It is the work produced by a normal workman, working at a normal rate under normal conditions, in one minute. Sixty Bedaux Units constitutes a standard

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Chas. E. Bedaux Co.,

normal hour's work. This is standard performance, and is required of every worker in the plant in order that he earn his base pay. To determine the standard performance correctly and exactly two fundamental activities must be initiated, and several variable factors must be determined: (*A*) time studies, and (*B*) motion studies. Before the development of light, portable motion picture equipment, time and motion had to be studied separately. Time studies were made with the stop-watch. Motion studies were made by observation. The two were not synchronized, and the human factor entered into both to a greater or less degree, depending upon the natural skill and the acquired training of the persons making the studies.

The motion picture photograph obviated this difficulty, accurately and permanently, but there still remained several important modifications or improvements to be made in the equipment itself. It was found, for example, that the ordinary 8-mm. spring-driven Ciné Kodak was not timed accurately enough for time studies. Having but one speed, which had a tendency to vary slightly in relation to the tension of the spring, constant winding was necessary, which made it rather awkward to use. Having no slow-speed attachment, its value for motion and job analysis was very limited. Requiring considerable space for the spring mechanism, *etc.*, it did not hold sufficient film for our purpose.

The equipment developed for time and motion study consists of an 8-mm. Ciné Kodak with a lens working at object distances of 2 feet. It is electrically driven, on any a-c. or d-c. circuit of voltage up to 130, the speed being regulated in part by a central rheostat at the back of the motor, but principally by a centrifugal governor. The camera exposes 1000 frames of Super Sensitive film per minute at normal speed, and 4000 frames at high speed. This gives us an exposure possibility of $^1/_{30}$ of a second for slow-motion work. It has been found that, here in California, on clear brilliant days, little, if any, artificial lighting is required. In any case, only one or two ordinary photoflood lamps and reflectors are required, set up at the proper distance and angle relative to the operation to be studied.

Eight-mm. Super Sensitive film is put up in 16-mm. reels. One half the width of the film is exposed at a time, the roll is then threaded for running in the reverse direction, and the other half is then exposed. The Bedaux measurement camera is designed to carry a maximum of 100 feet of 16-mm. film, or 200 feet of 8-mm. width. This provides 16 minutes' running time at standard speed, which is ample to cover practically any operating cycle. In fact, most cycles are so short that only a few feet of film are required for each one. Each cycle is, of course, identified by photographing its number and symbol from a number plate, after the study of the cycle is completed.

The photographic technic is but little more exacting than that required of a good amateur. However, the technic of the industrial engineer is considerably more professional than that. He is not concerned with the facial make-up, or expression of the face of the subject, at any rate. He wants an accurate story of time and motion. But the sets can not be staged. They must be the actual operations performed in the shop and the factory under ordinary working conditions. The movements of the hands must be seen, of the feet, the body, the manipulation of the machine, and the machine itself in operation.

In addition to modifying the camera, it was likewise necessary to alter and improve the projector. Knowing the taking speed to a split second was of little value unless the projection speed could be controlled. This was done by equipping the projector with a speedometer, a rheostat for controlling the motor speed, and a frame counter. With these attachments we are able to project film at speeds of 50 to 150 per cent of the normal running speed. By throwing a switch, the motor is cut out, and each frame can be projected as a still picture by means of a hand-crank. In addition, a method of loop projection has been developed. The film is cut at the end of an operation or cycle photographed, and the two ends are joined together to form a loop, which can be projected over and over again, slowed down or speeded up, or projected a frame at a time with the aid of the hand-crank, bringing the process or the machine and the operator literally into the laboratory.

Each frame is studied and analyzed. The analysis is transferred to an analysis sheet, where the study is continued. Wasted time of either hand, or both hands, is shown on the analysis sheet lined in red. Steps are taken to eliminate as largely as possible all waste time and unnecessary motion. A corrected operation is formulated, photographed, and analyzed, and the workers are trained to use the corrected method by projecting the new loop. The loops, and the analysis sheet taken from them, become permanent records of the machine, the process, and the time and motion involved. Each loop is filed in a humidifier cabinet with a card upon which has been catalogued the description and number of the loop.

These film loop records constitute a complete record of operations and equipment of great value to the industrialist. They bring time and motion studies together for analysis, and enable the sequence of motions to be studied and improved. Their use in job training for new employees must be obvious. Experienced operators who ordinarily are required to train the new workers may now remain at their work, while the new workers are trained in the best accepted method by means of the film loops.

In the case of the large manufacturer whose plants may be located at various geographical points, duplicate loops sent to these scattered plants or assembly stations show, in a language impossible to misinterpret, the management's approved method of operation; and as new and improved methods are developed, loops taken of the new process may be exchanged by the various plants. By the use of the loops, accurate Bedaux units, or *B* values, are set with a minimum of time and motion study. The system has been well received by labor, for the reason that it improves the accuracy of labor measurement and the establishment of correct fatigue allowances, and is regarded as an outstanding contribution to the field of industrial engineering. This equipment has been in actual use in applying Bedaux measurement and production control for the past year, and has made for itself a permanent place in time and motion studies and in job analysis. It has enabled us to measure and set accurate standards for types of work which heretofore offered considerable technical difficulties for visual observation.

WILLIAM KENNEDY LAURIE DICKSON

1860–1935

W. K. Laurie Dickson was born in France, of Scotch parentage, at Chateau St. Buc, Minihic-sur-Ranse in 1860. He came to the United States from England in 1879, and two years later was given a position by Thomas A. Edison in the Edison Electric Works, Goerk St., New York, N. Y., where he worked upon the standardization of electrical apparatus. Four years later, in 1885, he was transferred to Mr. Edison's private research laboratory at Newark, N. J.

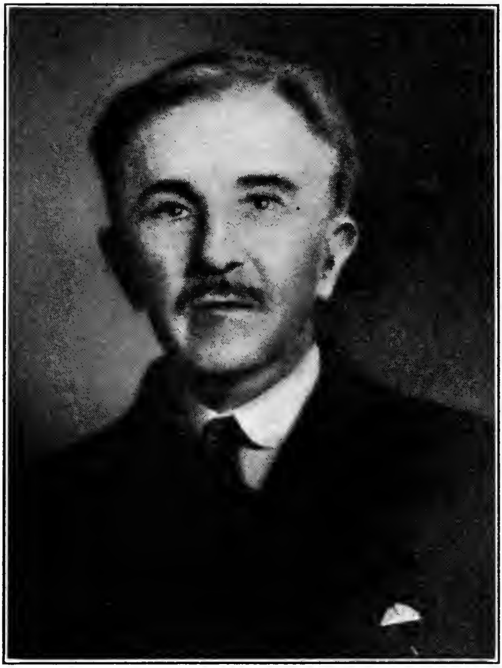
During the year 1887 he began work under Edison's supervision at the new laboratory building at Orange, N. J., upon a method of combining photography with the phonograph, or as Edison expressed it, "to devise an instrument that should do for the eye what the phonograph does for the ear, and that, by a combination of the two, all motion and sound could be recorded and reproduced simultaneously."

The experiments progressed rather slowly for lack of a suitable photographic recording material until December, 1888, when Dickson obtained experimental samples of a thin, transparent, rollable photographic film from George Eastman at Rochester, N. Y. Several types of intermittent movement had previously been tried out, and a modified Maltese cross was adopted in the Autumn of 1888.

Rapid progress was made with the design of the camera or "kinetograph" during the Spring and Summer of 1889. A fast negative emulsion was used at first, both for the negatives and the prints, but later a slow positive film was made available for printing. Several widths of film and picture sizes were used before the $1^3/_8$-inch film width and the $1 \times {}^3/_4$-inch picture size were adopted in 1889. These film and picture sizes remained the standard for the entire motion picture industry for many years, until the introduction of the photographic sound-track, about 1928, forced the adoption of a smaller picture size.

On October 6, 1889, Edison returned to his laboratory from an extended visit of several weeks in Europe. It was on that occasion that Dickson demonstrated for him the kineto-phonograph. This instrument consisted of a peep-hole kinetoscope modified to project a small picture from the continuously moving film. The pictures were synchronized with a phonograph record.

Edison did not believe at that time that the whole idea would be more than a passing fad, and, therefore, the continuous-motion kinetoscope was designed and sold as a peep-hole device and its audience was restricted to one person at a time. The film as finally adopted toward the end of 1889 had two rows of perforations, four to each picture, and these specifications have been used for motion pictures for the past 45 years.



William Kennedy Laurie Dickson,
1860–1935.

Dickson also devised equipment for developing and printing the film. He built the first motion picture studio in 1891-92, which came to be known as the "Black Maria," because of its tar-paper exterior covering. It was constructed upon a turntable so arranged that the entire structure could be rotated so as to follow the sun. A section of the roof was made to fold back to admit direct sunlight on the actors. Most of the subjects photographed were single acts of leading vaudeville stars of that period—1889–95. Each motion picture print was forty-seven feet long, and was released through Messrs. Raff and Gammon of New York, who were agents for the kinetoscope.

Dickson's work between the years 1887 and 1895, therefore, embraced almost every phase of development of the motion picture, with the exception of a practical projection device developed by Thomas Armat in 1895–96. Summarized, these developments included an intermittent camera using perforated film $1^3/_8$ inches wide, sprocket wheels, a friction pulley, and a tension gate; a developing outfit; a printer and a non-intermittent viewing device. He also synchronized several pictures with the phonograph, and directed and produced the first motion pictures that were shown commercially.

Although he left Edison's employ in 1895, he always praised his chief, and gave him and George Eastman the major credit for inventing the principal elements of the motion picture as it is known today.

In 1933 at the request of the Historical Committee of this Society, Mr. Dickson prepared a detailed account of his work and illustrated it with several interesting hand sketches and photographs.[1] This account included a discussion of his association with the American Mutoscope and Biograph Company, and the famous Patents Company that was formed in 1908. It describes also some of his experiences as a cameraman in Italy, where he was the first to make motion pictures of the Pope, and his photography of the Boer War.

On October 16, 1933, W. K. L. Dickson was elected to Honorary Membership in the Society. By his death on September 30, 1935, we have lost a distinguished colleague whose contributions to the birth of motion pictures were real and lasting.

GLENN E. MATTHEWS

REFERENCE

[1] DICKSON, W. K. L.: "A Brief History of the Kinetograph, the Kinetoscope, and the Kineto-Phonograph," *J. Soc. Mot. Pict. Eng.*, **XXI** (Dec., 1933), No. 6, p. 435.

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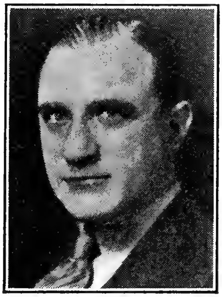

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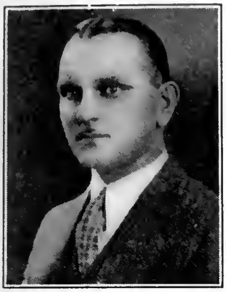

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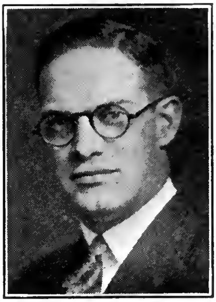

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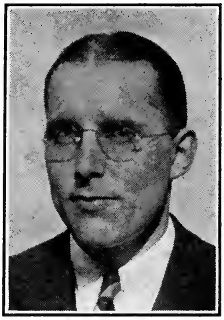

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HARCUS, W. C. (*M*)
HARPER, E. R. (*M*)
HARRINGTON, T. T. (*M*)
HARVEY, A. E. (*A*)
HEACOCK, F. C. (*A*)
HENSMAN, H. G. (*A*)
HOCH, W. C. (*A*)

Hoffman, L. B. (*M*)
Huse, E. (*F*)
Ingman, T. M. (*M*)
James, F. E. (*M*)
Jones, L. G. (*A*)
Kalmus, H. T. (*F*)
Kienninger, J. F. (*M*)
Kimball, H. R. (*M*)
Lambert, K. B. (*F*)
Lane, A. L. (*M*)
Larsen. P. J. (*F*)
Lentz, H. R. (*A*)
Leshing, M. S. (*F*)
Levinson, N. (*M*)
Lewis, W. W. (*A*)
Linderman, R. G. (*M*)
Livadary, J. P. (*A*)
Lucid, F. J., Jr. (*A*)
Ludlam, J. M. (*A*)
Maas, A. R. (*A*)
MacLeod, K. A. (*A*)
Margossian, M. (*A*)
McCroskey, H. E. (*M*)
McCullough, R. (*F*)
Melville, W. (*A*)
Meyer, H. (*F*)
Miller, R. P. (*A*)
Miller, V. E. (*A*)
Miller, W. C. (*F*)
Mitchell, G. A. (*F*)
Mitchell, G. S. (*M*)
Mole, P. (*F*)
Mols, P. M. (*A*)
Morgan, K. F. (*F*)
Moyse, H. W. (*F*)
Mueller, W. A. (*M*)
Nickolaus, J. M. (*F*)
Nielsen, J. F. (*A*)
Olmstead, L. B. (*A*)
Oster, E. (*A*)
Ownby, L. C. (*A*)
Paden, C. B. (*A*)
Phillips, J. H., Jr. (*A*)
Phillipps, L. C. (*F*)
Pohl, W. E. (*A*)
Prautsch, J. H. (*A*)
Preddey, W. A. (*A*)
Quinlan, W. (*M*)
Rackett, G. F. (*F*)
Reeves, A. (*M*)
Remerschied, H. W. (*M*)
Richardson, E. C. (*M*)
Ricker, M. (*M*)
Ridgway, D. W. (*A*)
Riley, R. (*A*)
Ross, E. (*M*)
Rudolph, W. F. (*M*)
Ruth, C. E. (*A*)
Ruttenberg, J. (*A*)
Ryder, L. L. (*M*)
Serrurier, I. (*M*)
Shultz, E. P. (*A*)
Siegel, J. (*A*)
Silent, H. C. (*F*)
Skinner, C. R. (*A*)
Smolinski, B. P. (*A*)
Spain, C. J. (*M*)
Stafford, J. W. (*A*)
Struss, K. (*F*)
Swett, W. C. (*M*)
Tasker, H. G. (*F*)
Thayer, W. L. (*A*)
Theisen, W. E. (*M*)
Thompson, F. B. (*A*)
Thompson, V. E. (*A*)
Tickner, A. J. (*A*)
Treacy, C. S. (*A*)
Trimble, L. S. (*A*)
Volck, A. G. (*M*)
Wernlein, C. E. (*A*)
Westheimer, J. (*A*)
Wild, S. J. (*A*)
Wilmot, H. T. (*A*)
Winn, C. B., Jr. (*A*)
Wise, A. G. (*M*)
Wolcott, E. A. (*M*)
Wolfe, W. V. (*A*)
Worrall, G. H. (*A*)
Wutke, L. M. (*A*)
Yesenskiy, A. P. (*A*)
Young, M. G. (*A*)
Zaugg, A. (*A*)
Zipser, S. (*A*)

Colorado

Alexander, D. M. (*M*)

FRANTZ, G. F. (*A*)
GRAHAM, H. (*A*)
HANNAN, J. H. (*A*)
STUBBS, J. A. (*A*)

Connecticut

AYERS, A. P., JR. (*A*)
BAKER, W. R. G., (*F*)
BLIVEN, J. E. (*M*)
CAMERON, J. R. (*F*)
COLLINS, D. W. (*A*)
HOLDEN, H. C. (*M*)
OLDHAM, C. (*A*)
PHELPS, L. G. (*M*)
ROGER, H. (*A*)

Delaware

HILL, M. H. (*A*)
HIRZEL, A. (*A*)
LYON, L. H. (*A*)
MARSH, H. N. (*A*)

District of Columbia

ARMAT, T. (*H*)
BENNETT, D. (*M*)
BRADLEY, J. G. (*A*)
CORRIGAN, J. T. (*M*)
COWLING, H. T. (*A*)
DAVIS, J. B. (*A*)
EVANS, R. (*F*)
GEORGENS, G. R. (*M*)
GILLETTE, M. E. (*M*)
GLASSER, N. (*M*)
GOLDEN, N. D. (*A*)
HAYTHORNE, R. N. (*A*)
HOPKINS, T. L. (*A*)
KILTON, G. C. (*A*)
KRUSE, W. F. (*A*)
MOORE, T. (*M*)
PETTERS, W. K. (*A*)
PRATT, J. A. (*A*)
SHIELDS, W. B. (*A*)
SMITH, J. E. (*M*)
STODTER, C. S. (*M*)
STORTY, F. J. (*A*)
TURVEY, C. F. (*M*)
WILDUNG, F. H. (*M*)

Florida

McGINNIS, F. J. (*A*)

Georgia

WEIL, N. (*A*)

Illinois

ANDRES, L. J. (*M*)
BAKER, G. W. (*M*)
BASS, C. (*M*)
BEAN, D. P. (*A*)
BEDORE, R. P. (*A*)
BUSCH, H. (*A*)
CHAPMAN, C. T. (*A*)
COX, L. R. (*A*)
DEPUE, B. W. (*M*)
DEPUE, O. B. (*F*)
DEVRY, H. A. (*F*)
FOOTE, P. C. (*A*)
FUNK, J. J. (*A*)
GAVER, E. M. (*A*)
HAMILTON, V. P. (*A*)
HECK, F. P. (*M*)
HOWELL, A. S. (*F*)
KLEERUP, B. J. (*M*)
LARUE, M. W. (*A*)
LUKES, S. A. (*M*)
MACOMBER, W. W. (*A*)
MATTHEWS, B. (*A*)
McAULEY, J. E. (*F*)
McNABB, J. H. (*F*)
MITCHELL, R. F. (*F*)
NELSON, E. W. (*A*)
NIEMANN, H. P. (*A*)
NORWOOD, D. W. (*M*)
RYAN, H. (*A*)
SAUNDERS, R. (*M*)
SCHAEFER, J. M. (*M*)
SCOTT, W. B. (*A*)
SHALKHAUSER, E. G. (*M*)
SHAPIRO, A. (*M*)
STECHBART, B. E. (*F*)
STONE, C. H. (*M*)

Tavernier, R. (*A*)
Venard, C. L. (*A*)
Wenzel, M. (*A*)
Zerk, O. U. (*M*)
Ziebarth, C. A. (*M*)
Zuber, J. G. (*M*)

Indiana

Freimann, F. (*F*)
Morris, L. P. (*A*)
Rossiter, D. R. (*M*)

Iowa

Rose, S. G. (*M*)
Spradling, J. W. (*A*)

Kansas

Baker, H. W. (*M*)
Brooks, G. E. (*A*)
Danielson, D. (*A*)

Louisiana

Frazier, L. (*A*)

Maine

Childs, J. A. (*A*)

Maryland

Barkman, C. (*A*)
Dusman, H. C. (*A*)
Green, R. B. (*A*)
Haefele, N. C. (*M*)
Murphy, G. D. (*A*)
Schminkey, H. K. (*A*)

Massachusetts

Aldridge, K. W. (*A*)
Barrows, T. C. (*M*)
Bishop, G. A., Jr. (*A*)
Brewster, J. R. (*A*)
Caddigan, J. L. (*M*)
Cifre, J. S. (*M*)
Cohen, J. H. (*M*)
Comi, E. G. (*A*)
Coolidge, P. E. (*A*)
Eager, M. (*A*)
Foster, L. L. (*A*)
Gibbons, J. M. (*A*)
Gleason, C. H. (*A*)
Gookin, F. M. (*A*)
Hardy, A. C. (*F*)
Judge, P. E. (*A*)
Lubao, R. (*A*)
Mauran, J. (*A*)
McKinney, H. J. (*A*)
McNamara, D. T. (*A*)
McRae, D. (*M*)
Murray, A. P. (*A*)
Narbut, L. A. (*A*)
Parris, R. C. (*A*)
Parshley, C. W. (*A*)
Pirovano, L. (*A*)
Reith, A. J. (*A*)
Savina, J. F. (*A*)
Scanlon, E. J. (*A*)
Smith, H. B. (*M*)
Smith, I. (*A*)
Sumner, S. (*M*)
Swartz, E. M. (*M*)
Taplin, J. (*A*)
West, A. B. (*A*)

Michigan

Anders, H. (*A*)
Avil, G. (*A*)
Biddy, R. (*A*)
Bradford, A. J. (*F*)
Brenkert, K. (*M*)
Chereton, A. B. (*A*)
Fenimore, R. W. (*M*)
Ganstrom, R. G. (*A*)
Hunt, H. H. (*A*)
Jarrett, G. J. (*M*)
Loy, L. C. (*A*)
McGlinnen, E. J. (*A*)
McMath, R. R. (*M*)
Miller, R. L. (*A*)
Pacholke, F. (*A*)
Richards, H. B. (*A*)
Schmitz, W. J. (*A*)
Strickler, J. F. (*M*)
Thomas, J. L. (*A*)

Thomas, W. F. (*A*)
Zatorsky, E. F. (*A*)

Minnesota

Greene, C. L. (*F*)
Karatz, T. (*M*)
Ray, R. H. (*M*)
Sly, E. C. (*M*)
Watkins, R. H. (*A*)
Wittels, J. M. (*A*)

Mississippi

Shotwell, H. H. (*A*)

Missouri

Alley, G. L. (*A*)
Bellinger, C. E. (*A*)
Bennett, R. C. (*M*)
Bub, G. L. (*A*)
Budde, H. (*M*)
Davis, D. R. (*A*)
Denney, W. (*A*)
Dwyer, A. J. (*A*)
Emmer, J. E. (*A*)
Fields, G. B. (*A*)
Gieskieng, M. W. (*A*)
Kelley, J. H. (*A*)
Matteson, N. (*A*)
Muller, J. P. (*M*)
Rankin, J. D. (*A*)
Thompson, L. (*A*)

Nebraska

Ballantyne, R. S. (*A*)
Jennings, D. V. (*A*)
Van Vleet, F. S. (*A*)

New Hampshire

Larson, I. J. (*A*)
Swist, T. P. (*A*)

New Jersey

Adatte, A. L. (*A*)
Aiken, C. C. (*A*)
Armstrong, H. L. (*A*)
Auger, E. (*A*)
Bachman, C. J. (*M*)
Baker, J. O. (*M*)
Bamford, W. B. (*A*)
Batsel, M. C. (*F*)
Baumann, H. C. (*A*)
Beggs, E. W. (*M*)
Bolton, W. A. (*A*)
Boman, A. (*A*)
Brewster, P. D. (*F*)
Burnap, R. S. (*F*)
Burnett, J. C. (*F*)
Busch, G. A. (*M*)
Buttolph, L. J. (*F*)
Cantor, C. E. (*A*)
Collins, M. E. (*A*)
Cook, E. D. (*A*)
Cook, H. R., Jr. (*A*)
Cozzens, L. S. (*M*)
Cunningham, R. G. (*M*)
Cunningham, T. D. (*A*)
Delvalle, G. A. (*A*)
Dickinson, E. A. (*A*)
Dimmick, G. L. (*A*)
Dobson, G. (*M*)
Dunning, O. M. (*A*)
Edison, T. M. (*A*)
Elderkin, J. K. (*M*)
Ellis, E. P. (*A*)
Emley, R. H. (*A*)
Foster, W. D. (*F*)
Frank, J., Jr. (*M*)
Gagliardi, G. (*A*)
Gaski, T. J. (*A*)
Goodman, A. (*A*)
Gove, K. G. (*A*)
Greene, P. E. (*A*)
Groves, I. R. (*A*)
Heney, J. E. (*M*)
Hohmeister, F. (*A*)
Holman, A. J. (*M*)
Hubbard, B. L. (*M*)
Jermain, H. F. (*M*)
Kellogg, E. W. (*A*)
Keuffel, C. W. (*M*)
Krehley, G. A. (*A*)
Kurlander, J. H. (*F*)

Lamb, R. T. (*A*)
Lansing, D. W. (*A*)
Lootens, C. L. (*M*)
Lutter, H. (*A*)
Macdonald, A. F. (*A*)
Manchee, A. W. (*M*)
Mason, C. (*A*)
McClintock, N. (*A*)
Mili, G. (*A*)
Miller, A. J. (*M*)
Miller, A. W. (*A*)
Moreno, R. M. (*M*)
Oakley, N. F. (*M*)
Perry, H. D. (*A*)
Porter, G. C. (*A*)
Reichard, E. H. (*A*)
Reifsteck, C. N. (*F*)
Rinaldy, E. S. (*A*)
Rockvam, A. O. (*A*)
Rockwell, H. P., Jr. (*A*)
Rubly, H. C. (*A*)
Sachtleben, L. T. (*A*)
Sattan, G. D. (*A*)
Scheibell, G. B. (*A*)
Schotofer, C. H. (*A*)
Sease, V. B. (*F*)
Smith, K. R. (*A*)
Solow, S. P. (*A*)
Sontagh, J. R. (*A*)
Stederoth, F. F. (*A*)
Stretch, A. T., Jr. (*A*)
Sunde, H. E. (*A*)
Tronolone, N. (*M*)
Waddell, J. H. (*A*)
Waddingham, A. G. (*M*)
Wagner, B. (*A*)
Walters, H. (*A*)
White, D. R. (*F*)
Williams, A. T. (*M*)
Willis, F. C. (*M*)
Willman, R. C. (*M*)
Wolferz, A. H. (*M*)
Wood, E. W. (*A*)
Yohr, M. J. (*A*)
Yeck, F. A. (*A*)
Zoeltsch, W. F. (*A*)

New York

Altman, F. E. (*A*)
Anderson, E. L. (*A*)
Arnold, P. (*M*)
Arnspiger, V. C. (*A*)
Austrian, R. B. (*A*)
Baker, T. T. (*A*)
Baltimore, D. M. (*A*)
Batchelor, J. C. (*A*)
Bauer, K. A. (*A*)
Beach, F. G. (*A*)
Bearman, A. A. (*A*)
Becker, A. (*A*)
Beers, N. T. (*M*)
Behr, H. D. (*A*)
Bell, A. E. (*A*)
Bendheim, E. McD. (*A*)
Berg, A. G. (*A*)
Berndt, E. M. (*M*)
Betts, W. L. (*M*)
Bielicke, W. P. (*M*)
Bird, C. L. L. (*A*)
Blair, G. A. (*F*)
Bloomberg, D. J. (*M*)
Bloomer, K. V. (*A*)
Bonn, L. A. (*M*)
Borberg, W. (*A*)
Bradshaw, D. Y. (*M*)
Brady, R. F. (*A*)
Brady, S. S. (*A*)
Breneman, G. H. (*A*)
Broadhead, D. T. (*A*)
Brock, G. (*M*)
Buensod, A. G. (*M*)
Burgundy, J. J. (*A*)
Burns, S. R. (*F*)
Byrne, W. W. (*A*)
Cahill, F. E., Jr. (*M*)
Capstaff, J. G. (*F*)
Carson, W. H. (*F*)
Carter, J. C. (*A*)
Carulla, R. (*M*)
Carver, E. K. (*F*)
Castagnaro, D. (*A*)
Catell, R. E. (*A*)
Caumont, N. (*A*)
Celestin, W. E. (*M*)

Cender, E. O. (*M*)
Chatterjee, R. N. (*A*)
Church, A. E. (*A*)
Clark, W. (*F*)
Cohan, E. K. (*M*)
Cohen, J. (*A*)
Coles, F. A. (*A*)
Comstock, T. F. (*A*)
Contner, J. B. (*M*)
Cook, A. A. (*M*)
Cook, O. W. (*M*)
Cook, W. B. (*F*)
Cousins, V. M. (*A*)
Crabtree, J. (*F*)
Crabtree, J. I. (*F*)
Crabtree, T. H. (*A*)
Crennan, O. V. (*A*)
Curtis, E. P. (*F*)
Cuthbertson, H. B. (*M*)
Davee, L. W. (*F*)
Deghuee, C. M. (*A*)
DeNapoli, A. C., Jr. (*M*)
DeRoberts, R. (*M*)
Deutscher, D. (*A*)
Devoe, E. M. (*A*)
Dickinson, A. S. (*F*)
Dillemuth, H. G. (*A*)
Dinga, E. W. (*A*)
Dix, H. W. (*F*)
Duisberg, W. H. (*A*)
Dwyer, R. J. (*A*)
Dykeman, C. L. (*M*)
Eckler, L. (*M*)
Edwards, G. C. (*F*)
Ehlert, H. H. (*A*)
Elmer, L. A. (*M*)
Emerson, M. (*A*)
Enderle, J. (*A*)
Engle, J. W. (*A*)
Evans, P. H. (*F*)
Evans, R. M. (*F*)
Famulener, K. (*A*)
Faulkner, T. (*M*)
Field, W. J. (*A*)
Finn, J. J. (*M*)
Fisch, L. B. (*M*)
Fisher, A. (*M*)
Flannagan, C. (*F*)
Fleischer, M. (*F*)
Flint, A. (*M*)
Flory, L. P. (*M*)
Forsyth, S. L. (*A*)
Foute, G. P. (*A*)
Fracker, E. G. (*M*)
Freedman, A. E. (*F*)
Friedl, G., Jr. (*M*)
French, R. R. (*M*)
Friend, H. H. (*M*)
Fritts, E. C. (*F*)
Gage, H. P. (*F*)
Gage, O. A. (*M*)
Gallo, R. (*A*)
Gaty, J. P. (*A*)
Gelb, L. (*A*)
Gent, E. W. (*M*)
Gercke, C. (*A*)
Germaine, M. (*A*)
German, W. J. (*M*)
Gilbert, F. C. (*M*)
Gilmour, J. G. T. (*A*)
Githens, A. S. (*A*)
Glauber, S. (*A*)
Glickman, H. (*M*)
Glunt, O. M. (*F*)
Goldman, M. (*A*)
Goldsmith, A. N. (*F*)
Grass, R. L. (*A*)
Green, N. B. (*F*)
Gregory, C. L. (*A*)
Griffin, H. (*F*)
Grignon, F. J. (*A*)
Grover, H. G. (*M*)
Guth, A. (*A*)
Hackel, J. (*M*)
Hall, F. M. (*M*)
Halpin, D. D. (*A*)
Hampton, L. N. (*M*)
Hardina, E. (*A*)
Harding, H. V. (*A*)
Harley, J. B. (*A*)
Harlow, J. B. (*M*)
Harris, C. E. (*A*)
Harrison, H. C. (*F*)
Heidegger, H. F. (*A*)
Henabery, J. E. (*A*)

HENKEL, J. F. (*A*)
HENNESSY, W. W. (*A*)
HERRIOTT, W. (*A*)
HIATT, A. (*M*)
HICKMAN, C. N. (*A*)
HICKMAN, K. (*F*)
HOCHHEIMER, R. (*M*)
HOGE, F. D. (*F*)
HOLLANDER, H. (*M*)
HOLSLAG, R. C. (*M*)
HOPKINS, J. J. (*M*)
HORNIDGE, H. T. (*M*)
HORNSTEIN, J. C. (*M*)
HORSTMAN, C. F. (*M*)
HUBBARD, R. C. (*F*)
HUMPHREY, G. H. (*A*)
HUNT, F. L. (*F*)
HYNDMAN, D. E. (*F*)
IRBY, F. S. (*M*)
IVINS, C. F. (*A*)
JOHNSON, B. W. (*A*)
JONES, J. G. (*F*)
JONES, L. (*A*)
JONES, L. A. (*F*)
JOY, J. M. (*M*)
KALLMAN, K. (*A*)
KEITH, C. R. (*M*)
KELLER, A. C. (*A*)
KENDE, G. (*M*)
KERKOW, H. (*A*)
KERST, W. D. (*A*)
KING, T. P. (*A*)
KLAUSSEN, B. (*A*)
KLEBER, J. O. (*M*)
KNOX, H. G. (*F*)
KOCSIS, P. (*A*)
KOHLER, J. J. (*A*)
KOSSMAN, H. R. (*A*)
KREUZER, B. (*M*)
KURTZ, J. A. (*A*)
LAKEWITZ, F. S. (*A*)
LANE, G. (*M*)
LANG, A. (*A*)
LAPAT, E. P. (*A*)
LAPORTE, N. M. (*F*)
LAWRENCE, J. F. (*A*)
LEE, A. A. (*A*)
LENIGAN, T. E. (*A*)
LENZ, F. (*A*)
LESTER, H. M. (*A*)
LEVENTHAL, J. F. (*F*)
LEWIN, G. (*M*)
LINS, P. A. (*M*)
LITTLE, W. F. (*F*)
LOTT, H. O. (*A*)
LUNDAHL, T. (*M*)
LUNDIE, E. S. (*A*)
MACILVAIN, K. H. (*A*)
MACLEOD, J. S. (*M*)
MACNAIR, W. A. (*F*)
MANHEIMER, J. R. (*M*)
MANN, R. G. (*A*)
MARCHESSAULD, C. E. (*A*)
MARKS, L. (*A*)
MARSHALL, F. R. (*A*)
MASTER, R. P. (*A*)
MATTHEWS, G. E. (*F*)
MAURER, J. A. (*A*)
MCBURNEY, J. W. (*M*)
MCGUIRE, P. A. (*F*)
MCLARTY, H. D. (*A*)
MEES, C. E. K. (*F*)
MESSITER, H. M. (*A*)
MIEHLING, R. (*M*)
MILLER, J. A. (*F*)
MILLER, O. E. (*A*)
MILLER, R. A. (*M*)
MINNERLY, N. H. (*A*)
MISENER, G. C. (*M*)
MITCHELL, M. N. (*A*)
MOSKOWITZ, J. H. (*A*)
MULLER, C. (*A*)
NADELL, A. (*M*)
NARIAN, S. (*A*)
NEU, O. F. (*M*)
NICHOLIDES, E. C. (*A*)
NICHOLSON, R. F. (*F*)
NIVISON, W. S. (*A*)
NIXON, I. L. (*F*)
NORLING, J. A. (*M*)
O'BRIEN, B. C. (*A*)
O'BRIEN, M. D. (*A*)
O'KEEFE, G. A. (*A*)
OSWALD, C. G. (*A*)
OWENS, F. H. (*A*)
PACENT, L. G. (*F*)

Palmer, M. W. (*M*)
Paulini, E. T. (*A*)
Peck, W. H. (*A*)
Perse, I. S. (*A*)
Pfannenstiehl, H. (*M*)
Pfeiff, C. (*M*)
Philipp, J. F. (*A*)
Ponde, D. B. (*A*)
Popovici, G. G. (*M*)
Price, A. F. (*M*)
Prilik, M. R. (*A*)
Prince, L. S. (*A*)
Puller, G. (*A*)
Rabinowitz, D. J. (*A*)
Ramsaye, T. (*F*)
Rasmussen, R. T. (*M*)
Raven, A. L. (*M*)
Ray, M. (*A*)
Rayton, W. B. (*F*)
Renke, A. (*A*)
Repp, W. H. (*M*)
Reynolds, J. L. (*M*)
Richard, A. J. (*M*)
Richardson, F. H. (*F*)
Richter, A. (*A*)
Ries, P. D. (*A*)
Rifkin, J. L. (*M*)
Rist, K. (*A*)
Roberts, F. W. (*A*)
Robillard, P. M. (*M*)
Rodwell, L. A. (*A*)
Rogalli, N. J. (*A*)
Rogers, F. B. (*A*)
Rogers, F. B. (*A*)
Roland, E. C. (*A*)
Rollins, F. S., Jr. (*A*)
Rosensweig, M. (*M*)
Ross, A. (*A*)
Ross, C. (*M*)
Ross, C. H. (*A*)
Ross, O. A. (*M*)
Rubin, H. (*F*)
Russell, W. F. (*M*)
Sailliard, J. H. (*A*)
Salvino, S. (*A*)
Sandstone, J. (*A*)
Sandvik, O. (*F*)
Santee, H. B. (*F*)
Sawyer, J. W. (*A*)
Schabbehar, E. A. (*A*)
Schaeffer, F. H. (*A*)
Scharmann, P. G. (*A*)
Schlanger, B. (*M*)
Schmid, F. (*M*)
Schmidt, W. A. (*F*)
Schwengeler, C. E. (*M*)
Scott, D. W. (*M*)
Scriven, E. O. (*F*)
Shea, T. E. (*F*)
Sheppard, S. E. (*F*)
Shnipkin, D. (*A*)
Signor, G. H. (*A*)
Smack, J. C. (*A*)
Smith, F. (*A*)
Space, K. F. (*A*)
Spence, J. L., Jr. (*F*)
Sponable, E. I. (*F*)
Spray, J. H. (*F*)
Staud, C. J. (*M*)
Steele, L. L. (*M*)
Steiner, R. (*A*)
Steinhof, E. G. (*M*)
Steponaitis, A. (*A*)
Stoller, H. M. (*F*)
Stone, J. H. (*A*)
Strock, R. O. (*M*)
Talwar, R. C. (*A*)
Tann, W. L. (*A*)
Tanney, J. A. (*M*)
Teitel, A. (*A*)
Terpening, L. H. (*M*)
Terry, R. V. (*M*)
Tetzlaff, E. F. (*A*)
Thompson, W. S. (*A*)
Tizian, S. L. (*A*)
Toth, A. F. (*A*)
Townsend, L. M. (*A*)
Tuckerman, L. P. (*A*)
Tulpan, S. (*A*)
Tuttle, C. M. (*F*)
Tuttle, H. B. (*M*)
Tyler, K. (*A*)
Verlinsky, V. (*A*)
Victor, A. F. (*F*)
Vieth, L. (*A*)
Volf, C. A. (*A*)

WADE, F. H. (*A*)
WALL, J. M. (*F*)
WALL, W. I. (*A*)
WALLER, F. (*M*)
WALTER, H. L. (*A*)
WARD, E. J. (*M*)
WARD, J. S. (*F*)
WATSON, J. S., JR. (*F*)
WEBER, C. M. (*F*)
WENTE, E. C. (*F*)
WENZ, A. (*A*)
WESTON, J. C. (*A*)
WESTWATER, W. (*M*)
WHITMORE, W. (*M*)
WIGGIN, L. J. (*A*)
WILLARD, T. W. (*A*)
WILLIAMS, S. B. (*A*)
WILLIFORD, E. A. (*F*)
WILSON, C. K. (*M*)
WINKLER, F. W. (*A*)
WISSMANN, J. (*A*)
WOLF, S. K. (*F*)
WYND, C. L. A. (*M*)
YAGER, H. B. (*M*)
YOUNG, H. A. (*A*)
YOUNGER, C. A. (*A*)
ZANETTI, E. (*A*)
ZELONY, E. M. (*M*)

North Carolina

RAMSEY, R. W. (*A*)
STONE, W. P. (*A*)

Ohio

CANADY, D. R. (*M*)
CARLSON, F. E. (*A*)
CARPENTER, E. S. (*M*)
COPLEY, J. S. (*A*)
CROSS, W. E. (*A*)
CUNNINGHAM, O. J. (*A*)
DASH, C. C. (*M*)
DOWNES, A. C. (*F*)
ESHELMAN, G. M., JR. (*A*)
FARNHAM, R. E. (*F*)
FLANAGAN, J. T. (*M*)
GARDINER, F. R. (*A*)
GEIB, E. R. (*F*)
GELMAN, J. N. (*M*)
GILES, R. H. (*M*)
GILSDORF, W. R. (*A*)
GORDON, I. (*A*)
HAMILTON, S. H. (*A*)
HERTNER, J. H. (*M*)
JOY, D. B. (*F*)
KERMAN, E. W. (*A*)
KUNZMANN, W. C. (*F*)
LANGFORD, L. P. (*M*)
LEROY, C. (*A*)
McCORD, C. T. (*A*)
NELSON, O. (*M*)
PORTER, L. C. (*F*)
PRICE, G. W. (*A*)
READ, E. A. (*A*)
ROCK, J. B. (*A*)
RUSSELL, K. B. (*A*)
SHAFER, L. J. (*A*)
STEELY, J. D. (*A*)
STRONG, H. H. (*F*)
VALLEN, E. J. (*A*)
WATSON, E. M. (*A*)
WELMAN, V. A. (*M*)
WINKELMAN, H. (*A*)
WITT, E. H. (*A*)
WORSTELL, R. E. (*A*)

Oklahoma

BARBER, C. E. (*A*)
WOOD, W. H. (*A*)

Oregon

MILLER, R. (*A*)

Pennsylvania

ABRAMS, S. (*A*)
BETTELLI, F. J. (*A*)
BIBEN, B. F. (*A*)
BLOOM, R. B. (*A*)
BLUMBERG, H. (*A*)
CLARK, J. P. (*M*)
COHEN, C. (*A*)
COHEN, S. (*A*)
DAVIS, S. I. (*A*)
DEFRENES, J. (*M*)

- DEIVERNOIS, P. J. (*A*)
- ESSIG, A. G. (*A*)
- EVANS, G. W. (*A*)
- FREEMAN, A. B. (*A*)
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- IVES, F. E. (*H*)
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- NEILL, C. B. (*A*)
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Rhode Island

- ALTIERE, E. S. A. (*A*)
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South Dakota

- HARDMAN, W. F. (*A*)

Tennessee

- CROWE, H. B. (*A*)
- CURLE, C. E. (*A*)
- FERGUSON, D. C. (*A*)
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Texas

- CHAPMAN, A. B. (*A*)
- FRASCH, H. H. (*A*)
- HULAN, A. G. (*A*)
- JAMIESON, H. V. (*M*)

Virginia

- MCLEMORE, J. R. (*A*)

Washington

- BRADSHAW, A. E. (*M*)
- SHEARER, B. F. (*A*)

West Virginia

- DUDIAK, F. (*A*)
- MYERS, W. D. (*A*)

Wisconsin

- ELLIS, F. E., JR. (*A*)
- HUDSON, W. (*A*)
- OLSON, O. E. (*A*)
- RENIER, A. H. (*A*)
- SMITH, R. A. (*A*)

Argentina

- BRAGGIO, J. C. (*A*)

Australia

- ALLSOP, R. (*F*)
- BUDDEN, P. H. (*M*)
- BUSHBY, T. R. W. (*A*)
- CROSS, C. E. (*A*)
- DYSON, C. H. (*A*)
- EDWARDS, N. (*A*)
- FLINT, A. B. (*A*)
- HART, K. R. M. (*A*)
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- HIGGINS, T. G. (*A*)
- JEFFERY, F. A. (*A*)
- MURDOCH, S. E. (*A*)
- PARRISH, H. C. (*A*)
- ROUSE, J. J. (*M*)
- SARGENT, R. (*A*)
- SMITH, A. C. (*A*)
- VAUGHAN, R. (*M*)
- WRIGHT, A. (*A*)

Austria

- BOEHM, H. L. (*M*)
- BUCEK, H. (*A*)
- MUELLER, E. (*A*)
- SCHROTT, P. R. VON (*A*)
- THALLMAYER, H. J. (*A*)

Bermuda

MONKS, C. H. (*A*)

Brazil

BARZEE, G. W. (*A*)
PINTO, O. D. (*A*)

Canada

ALEXANDER, J. M. (*A*)
ARMAND, V. (*A*)
ATKINSON, S. C. (*A*)
BADGLEY, F. C. (*F*)
BATTLE, G. H. (*A*)
BOURNE, R. E. (*A*)
BOYLEN, J. C. (*M*)
BURNS, J. J. (*A*)
CARPENTER, H. J. (*A*)
CARTER, W. S. (*A*)
COOPER, J. A. (*A*)
DENTELBECK, C. (*M*)
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FOLEY, T. E. (*A*)
FOURNIER, G. (*A*)
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GOLDIN, H. (*A*)
HARRIS, E. (*A*)
HEWSON, J. H. (*A*)
HOAD, T. C. (*A*)
JECKELL, W. H. R. (*A*)
KERRIN, J. A. (*A*)
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LEWIS, B. C. (*A*)
MATHEWSON, E. G. (*A*)
McCLELLAND, T. H. (*A*)
McGUIRE, J. (*A*)
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OLIVER, W. J. (*A*)
PATTON, G. E. (*M*)
QUICK, C. J. (*M*)
RICHARD, J. (*A*)
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SHORNEY, C. R. (*A*)
SOPER, W. E. (*A*)
SPRAGUE, A. (*A*)
STRINGER, J. (*A*)
TURNBULL, A. D. (*M*)
ZUMAR, A. B. (*A*)

Canal Zone

KAPLAN, L. (*M*)

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CHOW, K. (*A*)
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HSU, S. F. (*A*)
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LAY, M. W. (*A*)
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TORNOVSKY, I. M. (*A*)
WONG, H. S. (*A*)
WONG, T. (*A*)

Cuba

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Czechoslovakia

BRICHTA, J. C. (*A*)

England

ALDERSON, R. G. (*A*)
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BUSH, A. J. (*A*)
CABIROL, C. (*M*)
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HUDSON, G. (*A*)
JOHN, W. E. (*M*)
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KERSHAW, C. (*F*)
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KING, H. V. (*A*)
LAMB, E. E. (*M*)
LAWLEY, H. V. (*M*)
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LUKE, E. (*M*)
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NIEPMANN, C. H. (*M*)
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OSBORNE, A. W. (*M*)
OSMAN, D. E. (*A*)
PARKINS, C. F. (*M*)
PLANSKOY, L. (*M*)
PONTIUS, R. B. (*A*)
RENWICK, F. F. (*F*)
ROGERS, J. E. (*M*)
ROWSON, S. (*F*)
RUOT, M. (*F*)
SCARLETT, J. J. Y. (*A*)
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SKITTRELL, J. G. (*M*)
SMITH, J. W. W. (*A*)
TERRANEAU, R. (*F*)
TOUZE, G. (*M*)
TUCK, F. A. (*M*)
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WATKINS, S. S. A. (*F*)
WEBBER, A. C. (*A*)
WIDDOWS, C. G. (*A*)
WILLIAMS, G. A. (*A*)
WILLIAMSON, T. H. (*A*)
WILSON, S. K. (*A*)
WINTERMAN, C. (*M*)
WOLFF, E. H. (*A*)
WRATTEN, I. D. (*F*)

France

ABRIBAT, M. (*M*)
ALBERT, G. (*A*)
ASCHEL, H. (*A*)
BERTIN, H. (*M*)
BUREL, L. H. (*A*)
BURNAT, H. (*A*)
CARRERE, J. G. (*A*)
CHEFTEL, A. M. (*M*)
CHRETIEN, H. (*F*)
CORDONUIER, J. (*A*)
COTTET, A. (*A*)
COURMES, M. (*A*)
DALOTEL, M. (*M*)
DE BRETAGNE, J. (*A*)
DEBRIE, A. (*F*)
DIDIEE, L. J. J. (*A*)
EGROT, L. G. (*M*)
FIELD, A. (*A*)
FISHOFF, L. A. (*A*)
GERNOLLE, N. (*A*)
HOPPIN, C. (*A*)
HOTCHKISS, F. H. (*M*)
KELBER, M. (*A*)
KRAEMER, G. I. (*M*)
LAIR, C. (*M*)
LAWRENCE, T. (*M*)
LECOQ, J. (*A*)
LESLIE, F. (*A*)
LIVERMAN, C. (*A*)
LUMIÈRE, L. (*H*)
MARESCHAL, G. (*A*)
MARETTE, J. (*M*)
MATHOT, J. A. (*M*)
NATAN, B. I. (*A*)
SCHMITZ, E. C. (*M*)
STEINER, W. J. F. (*A*)
THEREMIN, W. (*A*)
WILD, G. (*M*)

Germany

BIELICKE, W. F. (*F*)
BUSCH, L. N. (*M*)
BUSSE, F. (*F*)
DAEHR, H. (*A*)
ENGL, J. B. (*F*)
GEYER, W. (*M*)
JOACHIM, H. E. A. (*M*)
KRASNA-KRAUS, A. (*M*)
LICHTE, H. (*F*)
LINGG, A. (*A*)
LUMMERZHEIM, H. J. (*M*)
MECHAU, E. (*F*)

Peterson, F. W. (*M*)
Reeb, O. G. L. (*M*)
Roseman, I. (*M*)
Rosenthal, A. (*A*)
Waschneck, K. (*M*)

Hawaii

Araki, J. K. (*A*)
Baker, R. J. (*A*)
Farver, B. R. (*A*)
Faust, A. (*A*)
Ferrena, W. C. (*A*)
Funatsu, H. K. (*A*)
Iwao, W. F. (*A*)
King, R. P. (*A*)
La Chapelle, L. (*M*)
Learnard, H. P. (*A*)
Lewbel, S. (*A*)
McKee, T. A. (*A*)
Woodward, E. K., Jr. (*A*)

Holland

Halbertsma, N. A. (*A*)
Kotte, J. J. (*A*)
Timmer, A. L. (*A*)
Van Breükelen, J. (*A*)

Hungary

Lohr, J. F. (*M*)
Morton, T. (*A*)

India

Ahluwalia, B. S. (*M*)
Arora, P. N. (*A*)
Bakhshi, M. N. (*A*)
Bali, D. N. (*A*)
Bhalchandra, M. C. (*A*)
Fazalbhoy, Y. A. (*A*)
Gogate, G. G. (*A*)
Gupta, D. K. (*A*)
Handa, D. (*A*)
Handa, G. C. (*A*)
Jadav, B. V. (*A*)
Lal, G. D. (*M*)
Leishman, E. D. (*M*)
Malhtra, M. N. (*A*)
Mathur, R. D. (*A*)
Mehta, H. S. (*M*)
Mistry, D. L. (*M*)
Mistry, M. L. (*M*)
Motwane, V. G. (*M*)
Nigan, C. S. (*A*)
Patel, K. K. (*A*)
Patel, M. B. (*A*)
Phatak, R. K. (*A*)
Pu, M. N. (*A*)
Shantaram, V. (*M*)
Shirodkar, G. N. (*A*)
Sohoni. B. A. (*M*)
Soi, B. N. (*A*)
Subedar, P. C. (*A*)
Sutaria, S. F. (*A*)
Tendulkar, H. D. (*M*)
Torney, R. G. (*A*)

Italy

Amati, L. (*A*)
Bittmann, H. (*A*)
Cecchi, U. (*A*)
De Feo, L. (*M*)
Finardi, E. V. (*A*)
Rossi, P. (*A*)
Trentino, V. (*A*)

Japan

Aikawa, S. (*A*)
Aochi, C. (*A*)
Aoyama, K. (*A*)
Asano, S. (*A*)
Corbin, R. M. (*M*)
De Mallie, R. B. (*M*)
Haruki, S. (*F*)
Helbling, W. E. (*A*)
Hirasawa, I. (*A*)
Kamei, K. (*A*)
Kano, J. H. (*A*)
Kasai, K. (*A*)
Kondo, T. (*A*)
Manpoh, K. (*A*)
Masaoka, K. (*A*)
Masutani, R. (*A*)
Matsuzawa, M. (*A*)

Mino, T. J. (*A*)
Nagase, T. (*M*)
Ohta, V. (*A*)
Osawa, Y. (*M*)
Saeki, R. E. (*A*)
Shimazaka, K. (*A*)
Sugiura, R. (*M*)
Tamamura, K. (*A*)
Tanaka, E. (*A*)
Tsuchihashi, H. (*A*)
Yasui, S. (*A*)

Mexico

De Perez, J. (*A*)
Fernandez, M. A. (*A*)

New Zealand

Banks, C. (*M*)
Blenkarne, P. C. (*A*)
Darby, E. (*A*)
Doddrell, E. T., Jr. (*A*)
Donald, J. McL. (*A*)
Fountain, A. (*A*)
Gill, K. (*A*)
Hodgson, W. (*A*)
Sparks, F. (*A*)
Steed, R. C., Jr. (*A*)
Vinsen, S. E. (*A*)
Wheeler, E. A. (*A*)
Wheeler, W. L. (*A*)
Wyatt, C. (*A*)

Norway

Gihbsson, L. (*A*)

Philippine Islands

Perry, C. (*A*)

Poland

Falquet, A. (*A*)
Rochowicz, S. (*A*)

Portugal

Eder, F. B. (*M*)

Roumania

Orban, R. F. (*M*)

Russia

Chorine, A. F. (*M*)
Jachontow, E. G. (*M*)

Scotland

Crawford, W. C. (*A*)
Hamilton, D. W. (*A*)
Jay, R. L. (*M*)
Poole, G. F. (*A*)

Spain

Aragones, D. (*M*)
Blanck, R. M. (*M*)
Blanco, E. (*A*)
Bueno, P. G. (*A*)
de Urgoiti, R. N. (*M*)
Morral, F. R. (*A*)
Robert, A. R. (*A*)
Tejero-Sanz, M. (*A*)
Zeppelin, H. V. (*A*)

Switzerland

Hess, H. P. (*A*)

Wales

Parlby, W. C. (*A*)

SPRING, 1936, CONVENTION

CHICAGO, ILLINOIS
EDGEWATER BEACH HOTEL
APRIL 27–30, INCLUSIVE

Officers and Committees in Charge

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HEADQUARTERS

The Headquarters of the Convention will be the Edgewater Beach Hotel, where excellent accommodations and Convention facilities are assured. A special suite will be provided for the ladies. Rates for SMPE delegates, European plan, will be as follows:

One person, room and bath	$3.00
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	5.00
Parlor suite and bath, for two	10.00 and 12.00

Room reservation cards will be mailed to the membership of the Society in the near future, and every one who plans to attend the Convention should return his card to the Hotel promptly in order to be assured of satisfactory accommodations.

A special rate of fifty cents a day has been arranged for SMPE delegates who motor to the Convention, in the Edgewater Beach Hotel fireproof garage. Private *de luxe* motor coaches operated by the Hotel will be available for service between the Hotel and the Chicago Loop area.

TECHNICAL SESSIONS

An attractive program of technical papers and presentations is being arranged by the Papers Committee. All sessions and film programs will be held in the *East Lounge* of the Hotel.

APPARATUS EXHIBIT

An exhibit of newly developed motion picture apparatus will be held in the *West Lounge* of the Hotel, to which all manufacturers of equipment are invited to contribute. The apparatus to be exhibited must either be new or embody new features of interest from a technical point of view. No charge will be made for space. Information concerning the exhibit and reservations for space should be made by writing to the Chairman of the Exhibits Committee, Mr. O. F. Neu, addressed to the General Office of the Society.

SEMI-ANNUAL BANQUET

The Semi-Annual Banquet and Dance of the Society will be held in the Ballroom of the Edgewater Beach Hotel on Wednesday, April 29th, at 7:30 P.M. Addresses will be delivered by eminent members of the motion picture industry, followed by dancing and entertainment.

INSPECTION TRIPS

Arrangements may be made, upon request at the registration desk, to visit and inspect, in small groups, various laboratories, studios, and equipment man-factories in the Chicago area. Firms that have extended invitations to such groups are:

- Burton Holmes Films, Inc.
- Bell & Howell Company
- Chicago Film Laboratories, Inc.
- Da-Lite Screen Company, Inc.
- Enterprise Optical Manufacturing Company
- Herman H. DeVry, Inc.
- Holmes Projector Company
- J. E. McAuley Manufacturing Company
- Jam Handy Pictures Corp.
- Jenkins & Adair, Inc.
- National Screen Service, Inc.
- Western Electric Company
- Wilding Picture Productions, Inc.
- Society of Visual Education

POINTS OF INTEREST

To list all the points of interest in and about Chicago would require too much space, but among them may be mentioned the following:

- Field Museum of Natural History
- Adler Planetarium and Astronomical Museum
- Art Institute
- Museum of Science and Industry
- Chicago Historical Society
- Academy of Science
- Lincoln Park
- Oriental Institute
- John G. Shedd Aquarium
- Lincoln Park Aquarium
- Lincoln Park Zoological Gardens
- Chicago Zoological Gardens
- Grant Park
- University of Chicago
- Loyola University
- Northwestern University

Complete information concerning and directions for visiting these places will be available at the Hotel.

RECREATION

A miniature nine-hole golf course, putting greens, and regulation tennis courts, maintained by the Hotel, will be available to SMPE delegates registered at the Hotel. Details will be available at the registration desk. Special diversions will be provided for the ladies, and passes to local theaters will be available to all delegates registering.

PROGRAM

Monday, April 27th.

9:00 a.m.	Registration Society business
10:00 a.m.–12:00 p.m.	Committee reports Technical papers program
12:30 p.m.	Informal Get-Together Luncheon for members, their families, and guests. Several prominent speakers will address the gathering.
2:00 p.m.–5:00 p.m.	Technical papers program
8:00 p.m.	Exhibition of newly released motion picture features and shorts.

Tuesday, April 28th.

10:00 a.m.–12:00 p.m.	Technical papers program
2:00 p.m.–5:00 p.m.	Technical papers program The evening of this day is left free for recreation, visiting, *etc.*

Wednesday, April 29th.

10:00 a.m.–12:00 p.m.	Technical papers program The afternoon of this day is left free for recreation and for visits to the plants of various Chicago firms serving the motion picture industry.
7:30 p.m.	Semi-Annual Banquet and Dance of the SMPE: speakers and entertainment.

Thursday, April 30th.

10:00 a.m.–12:00 p.m.	Technical papers program
2:00 p.m.–5:00 p.m.	Technical papers program Society business Adjournment of the Convention

ATTENTION! AUTHORS OF PAPERS

The time allotted for presentation of papers at the next meeting has been restricted by the Board of Governors of the Society. Morning sessions will begin at 10:00 A.M. and close promptly at 12:00 noon. Afternoon sessions will begin at 2:00 P.M. and close promptly at 5:00 P.M. It is, therefore, very important that all authors consider carefully the problem of presenting their papers in the most effective manner. The following suggestions represent useful ideas which every author should read and apply when delivering his paper.

(*1*) *Arrangement of Material.*—Manuscripts prepared for publication are seldom suitable for oral presentation. The paper should convey clearly to the listener: (*a*) the purpose of the work; (*b*) the experimental method; (*c*) the results obtained; and (*d*) conclusions. The nature of the material and the time available for presentation will determine the emphasis to be placed upon each subdivision. The author should make certain, by trial with his watch, that the essential points can be adequately presented in the time allotted to the paper.

(*2*) *Statement of Purpose.*—Orient the audience clearly as to the nature and purpose of the work. A lengthy historical review is generally out of place.

(*3*) *Technic.*—Describe the experimental method employed so as to indicate the principles involved. Omit details of apparatus or procedure unless there is some particularly novel development. Such data may belong in the published paper but may bore the audience.

(*4*) *Statement of Results.*—Present the results graphically, preferably with diagrams. Lantern slides are more clearly seen than hand-drawn charts. The slides should be of standard size (3.25 × 4 inches) and should project clearly upon the screen. Regardless of who has made the charts or slides, try them from the point of view of the audience before presenting them at the meeting. Do not read tables, a procedure that wastes time and destroys interest; but point out the general trend of the data. Whenever possible, the results of research should be shown by means of motion pictures, for which adequate projection facilities will be available.

(5) *Conclusions.*—Summarize the evidence and discuss the importance of the results or conclusions to the particular field of research involved.

(6) *Manner of Presentation.*—Do not read from a manuscript verbatim, unless the material has been written expressly for oral presentation. Speak directly to the audience in a clear, loud voice. Do not face the blackboard or the screen while speaking. Articulate distinctly.

Many exceptions to, and modifications of, the suggestions given above may apply in particular instances. Nevertheless, general adherence to the points brought out will go far toward eliminating the valid criticisms which have been aimed at our programs.

Acknowledgment is made to the Society of American Bacteriologists and the American Chemical Society for many of the ideas incorporated in these suggestions.

G. E. MATTHEWS, *Chairman, Papers Committee*

SOCIETY SUPPLIES

Reprints of *Standards of the SMPE and Recommended Practice* may be obtained from the General Office of the Society at the price of twenty-five cents each.

A limited number of reprints remain of the Report of the Projection Practice Committee (Oct., 1935) containing the projection room layouts, and "A Glossary of Color Photography." These may be obtained upon request, accompanied by six cents in postage stamps.

Copies of *Aims and Accomplishments*, an index of the *Transactions* from October, 1916, to June, 1930, containing summaries of all the articles, and author and classified indexes, may be obtained from the General Office at the price of one dollar each. Only a limited number of copies remains.

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CONTENTS

JOURNAL
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See p. 462 for Technical Committees

REPORT OF THE COMMITTEE ON LABORATORY PRACTICE*

Summary.—*A descriptive report of current methods of handling photosensitive materials in motion picture laboratories; a résumé of practical methods of manipulating raw stock, picture negative, sound-track negative, duplicating picture and sound negative, regular positive prints, master positive prints, and special films in the various laboratories of the United States. In addition are presented descriptions of equipment in current use and the general arrangement and appointments of processing laboratories.*

I. Introduction

II. Layout of a processing laboratory

- (*A*) ***Governing factors***
    - (*1*) Location
    - (*2*) Capacity or total footage output
    - (*3*) Efficiency in construction
    - (*4*) Efficiency of operation
    - (*5*) Cleanliness
    - (*6*) Safety
        - (*a*) *Fire protection equipment*
            - (*i*) Sprinkler systems
            - (*ii*) Fire alarm systems
            - (*iii*) Partitioning, exits, and fire-resisting appliances
        - (*b*) *Electrical equipment*
            - (*i*) Equipment for hazardous and non-hazardous locations
            - (*ii*) Protection of equipment to prevent fires
    - (*7*) General
        - (*a*) *Operation*
        - (*b*) *Illumination*
        - (*c*) *Air-conditioning*

III. History of raw stock

- (*A*) ***Storage of raw stock in laboratory***
    - (*1*) Type of storage room
        - (*a*) *Humidity*
        - (*b*) *Temperature (wet-bulb and dry-bulb)*

IV. Method of comparing emulsions

- (*A*) ***Standards selected***
    - (*1*) Exposure

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

- (*2*) Sensitometry and processing (developing)
- (*3*) Densitometry and plotting characteristic curves
- (*4*) Interpretation of curves
- (*5*) Evaluation of curves

V. Printing

- (*A*) ***Types of printers***
  - (*1*) Contact (step and continuous)
    - (*a*) *Double system*
    - (*b*) *Single system*
  - (*2*) Optical
    - (*a*) *Picture step* (*reduction*)
    - (*b*) *Continuous sound reduction*
  - (*3*) Trick and special

- (***B***) ***Maintenance of printers***
  - (*1*) Electrical circuits
  - (*2*) Printing lamps (illumination sources)
  - (*3*) Machine drives (footage speeds)
  - (*4*) Printer light-change system
  - (*5*) Printer matching

- (***C***) ***System of printing***
  - (*1*) General procedure
    - (*a*) *Method of timing*
    - (*b*) *Manner of printing*
  - (*2*) Title making and printing
    - (*a*) *Superimposed titles*
    - (*b*) *Title insert printing*

VI. Processing

- (*A*) ***Types of machines***
  - (*1*) Design and construction
  - (*2*) Footage speeds

- (***B***) ***Development***
  - (*1*) Formulas
    - (*a*) *Original and replenisher supply*
      - (*i*) Negative type
      - (*ii*) Positive type
      - (*iii*) Sound-track types
      - (*iv*) Special types
    - (*b*) *Mix and method of agitation*
    - (*c*) *Temperature control*
  - (*2*) Machine footage speeds and development times
  - (*3*) Control methods (maintenance of constant density and gamma)
    - (*a*) *Negative control*

- (*b*) *Positive control*
- (*c*) *Sound-track control*
- (*d*) *Duplication control*
- (*e*) *Specialized control*

(*C*) ***Fixation and hardening***

- (*1*) Formulas
- (*2*) Temperature control
- (*3*) Time of fixation

(*D*) ***Wash water***

- (*1*) Fresh water supply
    - (*a*) *Source*
    - (*b*) *Mode of purification*
- (*2*) Time of washing
    - (*a*) *Preceding fixation*
    - (*b*) *Succeeding fixation*
- (*3*) Temperature control

(*E*) ***Drying conditions***

- (*1*) Type of air-conditioning system
    - (*a*) *Method of circulating* (*refer to* VI, *A*)
    - (*b*) *Velocity of air* (*refer to* **VI,** *A*)
- (*2*) Temperature control (wet-bulb and-dry-bulb)
- (*3*) Humidity
- (*4*) Time

(*F*) ***Film treatment***

- (*1*) For lubrication
- (*2*) For lubrication and preservation

VII. Method of Inspection

(*A*) ***Negative***
(*B*) ***Prints***

VIII. General air-conditioning

(*A*) ***Laboratory building***

- (*1*) Storage vaults
- (*2*) Printing rooms

I. INTRODUCTION

Specific phases of motion picture film development were discussed in reports by the Committee on Laboratory and Exchange Practice at two previous Conventions of the Society. This year the Committee was divided into two separate Committees—the Exchange Practice Committee and the Laboratory Practice Committee.

After careful consideration the newly organized Laboratory Practice Committee decided it would be best to present to the Society a tutorial report of the current methods of handling photosensitive materials in motion picture laboratories. As no general information on laboratory procedure had ever been published before, it was felt that a general summary of current laboratory practice might well serve as a helpful reference and would eventually lead to the Society's making recommendations and suggestions that would increase the ease of laboratory manipulation and improve both the photographic quality on the screen and the sound quality in the theater.

The following pages contain a résumé of some practical methods of manipulating picture negative, sound-track negative, duplicating picture and sound negative, regular positive prints, master positive prints, and special films in the various laboratories of the United States.

II. LAYOUT OF PROCESSING LABORATORY

There is probably no concrete method governing the layout of ideal floor plans for a motion picture processing laboratory, but rather, the special arrangements that are chosen depend upon the proportion of the different types of work that are done, the variations in the processes that are employed, and several other factors. In the planning some prime factors to be considered are the desirability of location; the total capacity or total footage; the efficiency of construction, as to building, floor plans, and equipment; the operating efficiency for maximum and minimum capacities within overhead expenditure; the cleanliness of each department; the safety factors; and the general problem of operation, illumination, and air-conditioning.

The location depends upon the availability of a site in proximity to the source of business and the source of power, raw materials, water, and other services. The total capacity or footage output is usually gauged upon the basis of present and future prospects for business. The most efficient construction avoids unnecessary walls, partitions, and inconvenient room shapes, and careful consideration is given to partitions in relation to the building structure and between rooms, vaults, and sections where film is stored. Attention is given to piping, electrical conduits, and ventilation duct layouts to minimize the cost of installation and construction. The flow of materials is so arranged that the plant can be operated efficiently and economically. Film should not be allowed to accumulate in any one place, and to avoid such accumulation suitable means of transportation from point to point are provided. When possible, the layout of the plant is such that each operation on the film follows in sequence, with the shipping department easily accessible to an exit but near the final handling room.

Extreme cleanliness must be observed if the ultimate in clean negatives and prints is to be attained. Walls and floor surfaces should be treated with paints or other materials that will collect a minimum of dust and dirt. Few laboratories are air-conditioned throughout the entire building, but when they are, their problem of cleanliness is lessened considerably.

A detailed description of sprinkler systems, fire-alarm systems, partitioning, exits, fire-resisting appliances, electrical equipment in hazardous and non-hazardous locations, and protection of electrical equipment to avoid fire hazards does not seem necessary in this report, as the choice of type and the installation of such equipment must be approved and accepted by the National Board of Fire Underwriters and must conform to the National Electrical Code, the local fire ordinances, and the electrical codes and factory laws as applied to the motion picture industry. The codes govern the safety factors, but often the manager of the laboratory assumes additional precautions for the protection of the plant and personnel and to reduce the insurance costs.

The general problems of operation, illumination, and air-conditioning are discussed in more detail in connection with the following descriptions of operating methods.

III. HISTORY OF RAW STOCK STORAGE

Immediately upon the receipt of any type of raw stock (regular printing positive, duplicating negative, master positive, and special emulsions) the majority of motion picture laboratories store it in a special room or storage vault set aside for the purpose. Before the raw stock is placed in the storage vault it is generally uncased, and the taped cans stored in an upright position in specially designed racks. In a few laboratories these rooms are air-conditioned, but in the majority of laboratories they are simply ventilated, and consequently the condition of the air in the storage room approximates general indoor atmospheric conditions. Usually the dry-bulb temperature ranges from 65° to 80°F., and the relative humidity ranges from 30 to approximately 70 per cent. Most laboratories have small vaults just off the printing room that are air-conditioned like the printing room. The film is given to the printers after it is untaped, uncanned, and the black paper removed. In laboratories where a conditioned room or a conditioned vault is not adjacent to the printing room, the film is taken directly from storage. Frequently, at the beginning of the working day, sufficient film is uncanned to supply the printers for that day or for an eight-hour period.

IV. METHODS OF EMULSION COMPARISON

As a standard of exposure for emulsion comparison and for control tests a number of laboratories now employ the Eastman type II*B* sensitometer (Fig. 1) for sensitometric testing, and in some cases various types of step tablet sensitometers (Fig. 2). For practical visual print comparison a carefully maintained continuous or step printer is sometimes employed using a selected picture negative as the light modulator.

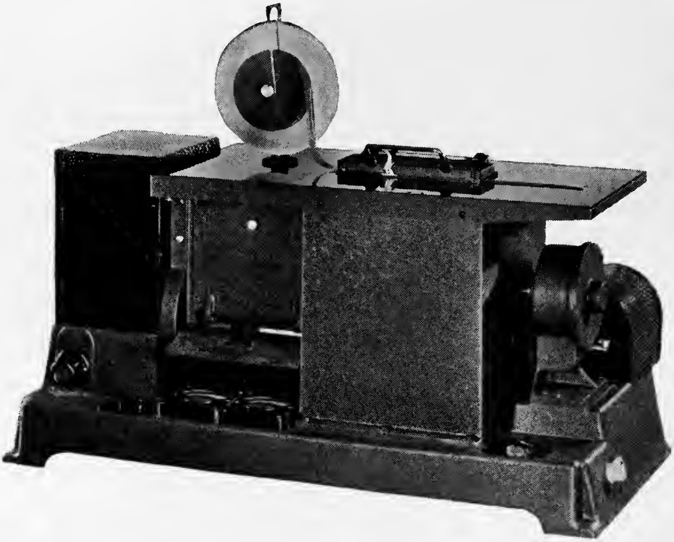


FIG. 1. Eastman II*B* sensitometer; for exposing sensitometric strips on all photosensitive materials.

The master printer for printing the negative selected as a standard of reference for picture quality is often given special attention. Special care is taken to keep the current supplied to the lamp constant, and the lamp is carefully inspected for defects and seasoned before use so as to assure uniformity of illumination at the gate. The uniformity of speed of the machines is also carefully checked. The care of printers and printing mechanisms will be discussed later.

Upon receipt of a new emulsion number of any raw stock it is accepted practice to impress upon 10- to 25-ft. lengths taken from one to five rolls (selected at random) of the new and the former coatings, two to five sensitometered strips on the sensitometer using the positive or negative set-up, according to the film being used.

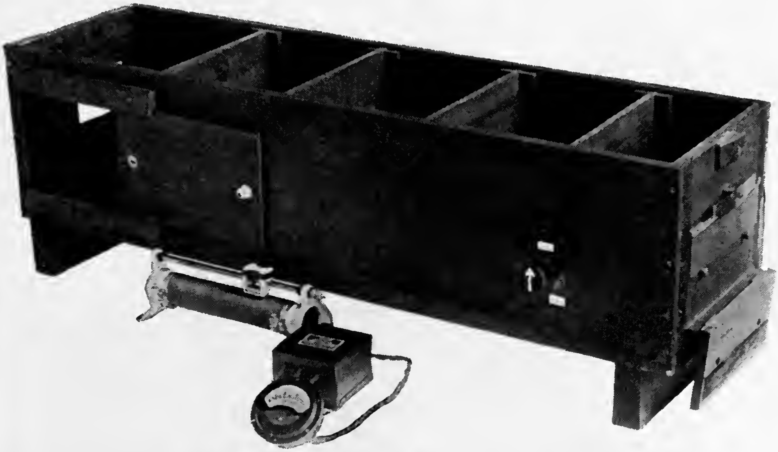
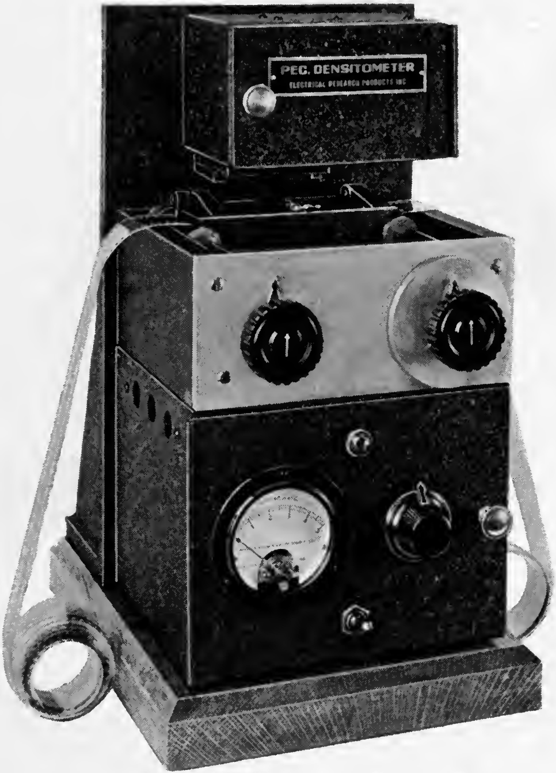


FIG. 2. Eastman model X step tablet sensitometer; for exposing sensitometric strips on all photosensitive materials.

Obviously, the positive set-up is used for those photosensitive materials that have positive film characteristics, and the negative set-up for those that have negative types of characteristics. Six- to 100-ft. lengths of both the new and the former emulsions are printed on the selected printer from the selected negative accepted as a standard of reference. The prints on all strips are made at the step setting that was correct for the former coating. All sensitometric strip exposures and prints are then developed together by the appropriate development process, either negative or positive, for the time that produced the desired gamma, density, and photographic quality that was adjudged satisfactory on the former coating. Then the step densities on the sensitometered strip are read on a suitable densitometer (Figs. 3, 4, and 5 illustrate some of the types available) and plotted by the recognized method described by Jones.[1] From the plotted, averaged, sensitometered strips the difference in gamma and density speed can be ascertained for the predetermined development time, and by visual judgment the timer can discern the change of printer point, if any, necessary to produce the same density in the new emulsion as was obtained in the former emulsion. Often a retest is made at the new printer point assignment, and the new emulsion is developed for the time necessary to produce in it a gamma equivalent to the gamma of the former emulsion, which is the gamma that the laboratory has determined to be the most suitable to obtain the best quality. This procedure is of particular importance in testing positive printing stock, as release prints must be held to fairly close tolerances to obtain uniform screen quality.

FIG. 3. Eastman direct-reading densitometer; for reading densities on all types of films and plates.

Often, after having completed the above-described tests of the new positive raw stock, prints are made of a production negative in work upon a 1000-ft. roll of the new and a 1000-ft. roll of the former emulsion. From this final test, by visual inspection, a printer point rating and a development time are assigned to the new emulsion so that prints made with the new emulsions will match approximately the quality obtained with the former emulsion. Sometimes laboratories depend upon their sensitometric tests, and assign printer point settings for positive emulsions by drawing perpendiculars from the point of unit density on the straight-line portion of the plotted characteristic curves to the abscissa, or log E axis, to determine the log E difference between the new and former emulsions. A difference in log E of 0.05 at equal gammas is equal to a change of about Bell & Howell model D printer point. This log E difference for printer point difference varies considerably from laboratory to laboratory, as each laboratory tends to design its own printer step difference when constructing printer light step resistance control panels.



(*Courtesy of Electrical Research Products, Inc.*)

FIG. 4. Photoelectric cell densitometer; for reading sound-track densities.

Positive emulsions from coating to coating are generally within the tolerance of laboratory manipulation for density and gamma, and, therefore, only slight changes in printer point ratings are necessary. If the new emulsion, however, is slightly higher or slightly lower in gamma than it should be, as compared with the previous emulsion, it is usually assigned a development time that will produce a gamma within the tolerance set by the laboratory. Gammas of positive prints vary from 1.9 to 2.3, but fall in the majority of laboratories within the range of 2.0 to 2.2. Most laboratories endeavor to maintain with positive prints a uniformity of gamma control from day to day of 2.0 to 2.2 or ±0.1. Some endeavor to maintain the control within ±0.05. The printer point variation is usually held within ±0.5 printer point, but some laboratories approve prints that have variations from day to day of ±1 Bell & Howell printer point, or the equivalent of ±0.05 in log E exposure value at a density of unity.

(Courtesy of Electrical Research Products, Inc.)

FIG. 5. *KS-6466* densitometer; for reading densities on all types of films and plates.

V. PRINTING

(*A*) *Types of Printers*

Practically all laboratories, regardless of their footage production, have several types of printers available for either routine release printing or special printing. Upon the introduction of sound into the motion picture industry, several laboratories decided that it was expedient and economical to make a few mechanical changes in their standard printing equipment to handle the sound printing problems, and this accounts to some extent for the variation in the types of printers being used.

Standard types of continuous and intermittent printers for image transfer are in use, but generally each laboratory makes a few changes in its printers to suit specific operating conditions and to offer greater ease of manipulation. The scope of this report, however, does not permit describing in detail the modifications that are made in design although an attempt will be made to cover more or less schematically the major changes.

For printing 35-mm. sound-track and picture negative the machine most commonly used is the Bell & Howell model *D* printer. Some of these printers are used just as manufactured, but most of them are modified in some way, particularly in the light-change mechanism. It is sometimes more efficient and economical to use single-operation printers, that is, printers in which the sound-track negative and the picture negative are printed simultaneously. Falling into this class are modified Bell & Howell printers, Duplex step printers, and special printers designed and constructed in accordance with the specifications of the particular laboratory.

In laboratories employing Bell & Howell continuous printers (Fig. 6) that have been revamped so as to print the sound-track and the picture negative simultaneously, a finished sound print is the result of passing the picture negative, the sound negative, and the positive raw stock continuously through the printer. In the case of one notable modification, the picture printing takes place on the sixty-four-tooth standard sprocket with the aperture so masked that the sound area is left unexposed and the sound printing takes place on a sprocket corresponding to the upper feed sprocket. This sprocket has been replaced with a specially designed thirty-two tooth, hollow-center printing sprocket suitably masked for sound printing and provided with the necessary shoe mechanism. The casting of the machine has been extended to provide for an additional sprocket above the sound printing sprocket in order that the strain of pulling the films from the flanges is not imposed upon the sprocket on which the sound printing takes place. The drive of this modified printer has been completely rebuilt so that the machine is now driven directly from a fractional

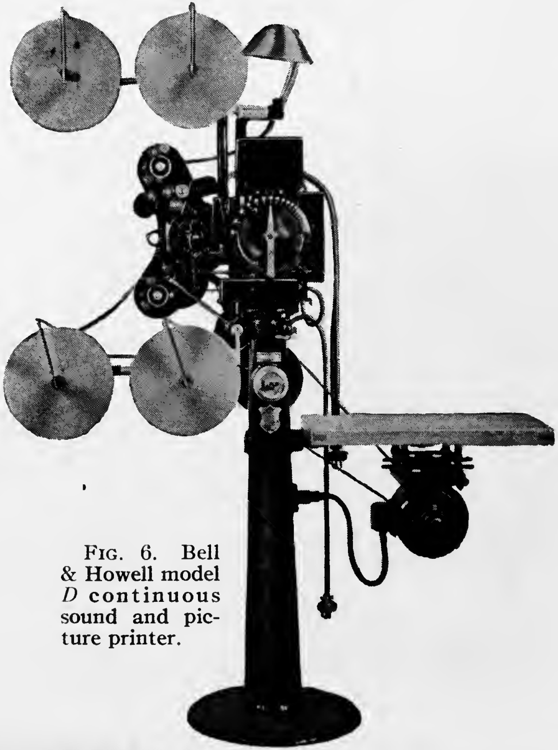


FIG. 6. Bell & Howell model *D* continuous sound and picture printer.

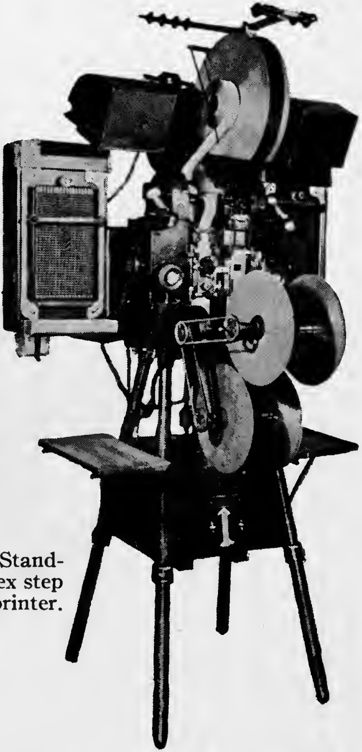


FIG. 7. Standard Duplex step picture printer.

(*Courtesy of Consolidated Film Industries, Inc.*)

horsepower semisynchronous motor. A flywheel has been mounted upon the shaft of the sound printing sprocket to insure steady motion. Printer mechanisms and light-change boards are constructed to permit printing forward and backward, thus avoiding the necessity of rewinding the negative after each printing. On some machines of this type use is made of the standard Bell & Howell picture shutter light-change mechanism, while others utilize specially designed resistance boards for the light-changes. Details of various types of light-change mechanisms will be outlined later.

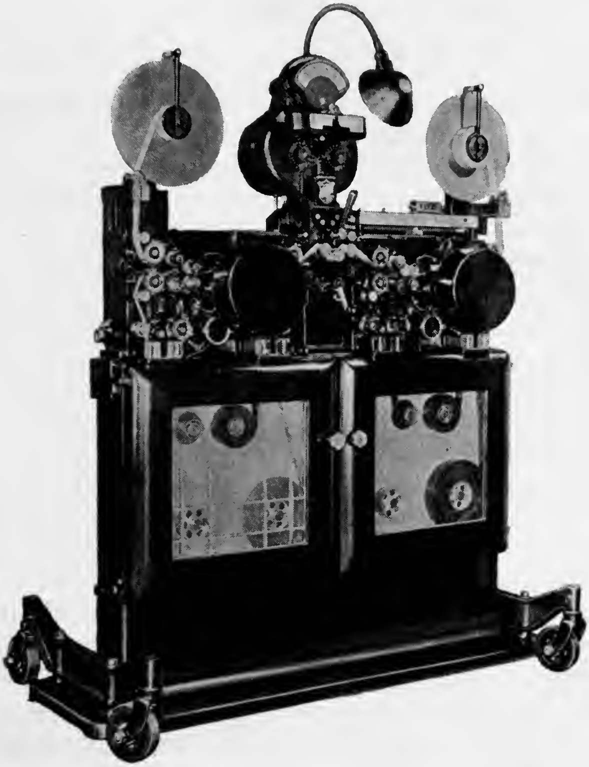


FIG. 8. Bell & Howell continuous sound and picture production printer.

Modified Duplex step printers (Fig. 7) for simultaneously step printing the picture negative and continuously printing the sound-track negative are in use. The adaptation is accomplished by attaching to and offsetting below the step picture printing head of the Duplex printer a continuously operated sound printing head in which the film is pulled over a curved gate with a balanced shoe mechanism. The sound printing head is run synchronously with the step printing head at a speed of approximately thirty-five to forty feet per minute. Both the picture and the sound-track light-change mechanisms are controlled by standard resistance boards modified in accordance with specifications of the laboratories.

Where continuous operation has approached its maximum, printers have been engineered so that the sound-track and the picture negative light-changes are controlled by specially prepared mattes that vary the light aperture opening for printing both sound and picture. These mattes are prepared for the timing of each reel of picture negative and sound-track negative printed. By automatically increasing or decreasing the intensity of the exposing lamp by means of a governing mechanism, these printers will permit using the matte timed to accompany a given sound-track or picture negative at various footage speeds.

The new Bell & Howell single-operation continuous sound-track and picture printer (Fig. 8) for printing both picture and track in one operation is now being used in a number of laboratories. Details of these printers have been previously published in the JOURNAL.[2] The light-change, scene for scene, is controlled by specially prepared mattes that vary the light aperture in the manner previously described. Details of the design and operation of this printer and of the continuous model *D* printer, in which the sound-track and the picture are printed in separate operations, can be obtained from the manufacturer. Several Depue continuous sound-track and picture printers using light-change resistance boards for timing are in use.

A few laboratories are using printers that are no longer manufactured, but by far the great majority use printers of the type described above. All the printers mentioned so far are used for standard release printing work.

Quad printers are sometimes used for printing news releases to increase the efficiency and decrease the time of production. These quad printers are groups of four printers driven by the same source of power, and may be combination step picture printers and sound-track continuous printers, or continuous picture and sound printers in which the sound-track and the picture are printed simultaneously. The negatives, both sound-track and picture, are run through all four machines, thus producing four complete prints with each pass of a negative. The light-change mechanisms are carefully matched, step for step, for each individual head in the battery of four, so that uniform prints may be obtained.

Printers equipped with so-called "five-way gates" eliminate negative rewinding and speed up production. These "five-way gates" are movable masks in the printing aperture, which change position and permit the sound-track to be printed first along one edge of the positive and then along the other, as the sound-track position reverses when the negative is printed backward.

Each laboratory has special optical printers (Figs. 9 and 10) for making wipe-outs, lap dissolves, inserts, *etc.*, in addition to the standard types of continuous and step optical printers. Generally, however, these printers are assembled from standard cinema machinery obtained on the commercial market. In many instances, printers of this type are built in accordance with the particular specifications of the laboratory so that unusual photographic effects may be achieved. To describe the various types of special printers would be an endless task and, since most printer manufacturers will make special printers for effect purposes, detailed information upon the subject can be obtained from them.

Because of the problem involved in superimposing foreign titles for foreign release prints by methods that will be described later, special printers have been designed that will print in one operation the sound-track negative, picture negative, and title from a single frame upon the picture area of the positive. The firms that have constructed these printers have reduced their production cost and achieved a greater ease of manipulation in making foreign release prints.

Due to the increasing demand for 16-mm. sound-film prints, a number of laboratories have either purchased, or had constructed according to their specifications, continuous optical reduction printers for reducing 35-mm. sound-track negative to 16-mm. sound-track positive (Figs 11–15). Usually these printers are designed for reducing the sound-track only, the picture being reduced in one of the standard types of 35–16-mm. step optical reduction printers.

(*B*) *Maintenance of Printers*

(*1*) *Electrical Circuits.*—All printing lamp lines to the various machines are generally of ample size to reduce the line drop to a

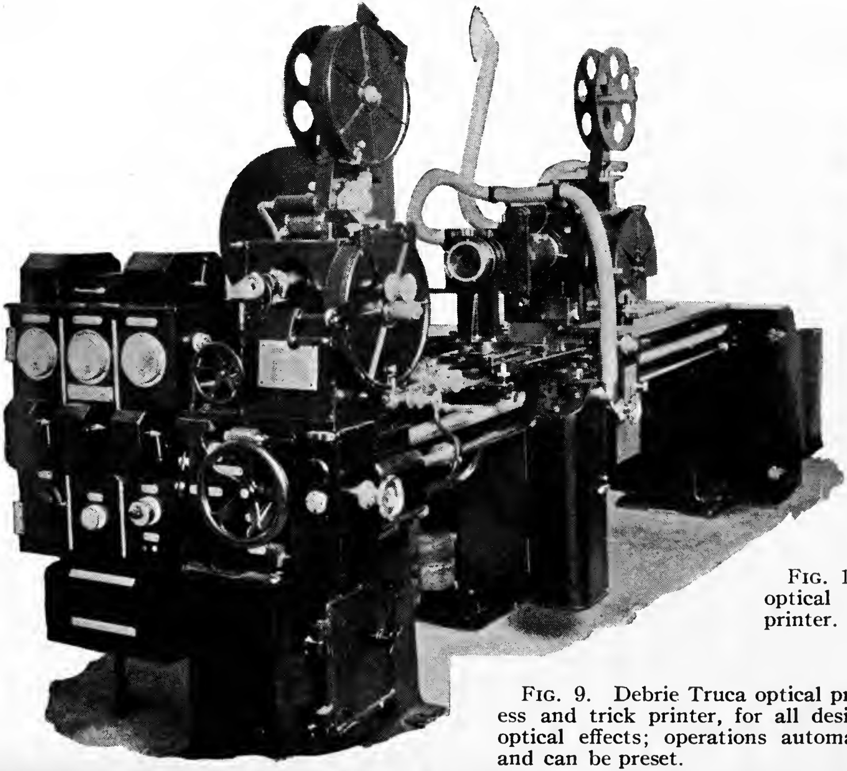


FIG. 9. Debrie Truca optical process and trick printer, for all desired optical effects; operations automatic and can be preset.

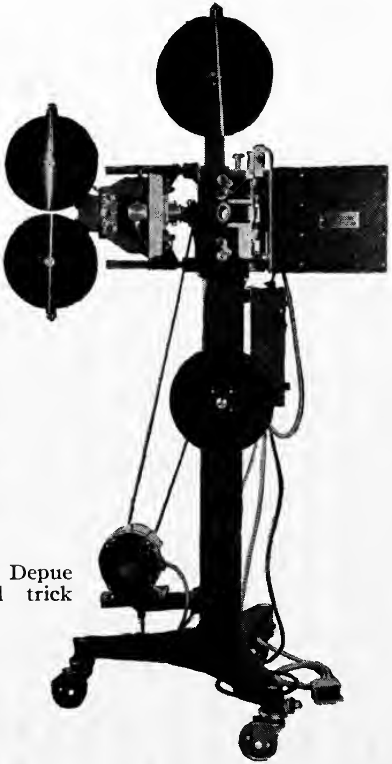


FIG. 10. Depue optical and trick printer.

minimum, and direct current is invariably used. In most laboratories an attempt is made to lay out the printer room so that the distribution of current to adjacent machines is not affected when any one machine is switched on or off. Printing lamp current is commonly provided by an independent d-c. generator, so that voltage regulation can be maintained within ±0.5 volt. Frequently, special converters are used so that the supply will not vary more than ±0.5 volt for a 10 per cent change of line voltage supplied to the converter.

(*2*) *Printing Lamps.*—As sources of illumination, printing lamps of suitable characteristics are selected, with particular regard for their ruggedness and durability. Generally, lamps of greater wattage than necessary are chosen, in order that they may be operated well below their rated voltage and so maintain reasonably constant color temperatures throughout their lives. Often lamps are selected according to photometric and electrical measurements to assure uniform characteristics. Usually, when using resistance light-changes, printer lamps are so matched that the voltage-current characteristics are similar. In most laboratories the filament alignment and the positions of the lamps in the machines are checked daily, and exposure tests are made frequently to check the illumination levels of the printers.

(*3*) *Machine Drives* (*Footage Speeds*).—Semisynchronous motors are sometimes used to simplify the problem of maintaining the speed of the printing machines constant. Special attention is generally given to eliminating vibration, especially in the case of printers that are not mounted upon solid, heavy foundations. Printers that have been specially designed and constructed by the laboratories are usually built into very heavy foundations to guard against vibration. It is common practice to drive Duplex step printers at speeds of thirty-five to forty feet a minute whether they be single-operated or operated in conjunction with specially designed continuous sound printing heads. Bell & Howell continuous printers, whether of the single-aperture type or the modified combination sound and picture aperture type, are driven at speeds varying from sixty to one hundred and twenty-five feet a minute. Where special continuous printers that print the picture and the sound-track simultaneously are operated in direct conjunction with continuous processing machines, the speeds vary from one hundred and twenty-five feet to one hundred and eighty feet a minute. It can be expected that the speed at which the printers are driven depends upon the footage production of the laboratory and the mechanical limitations of the machines.

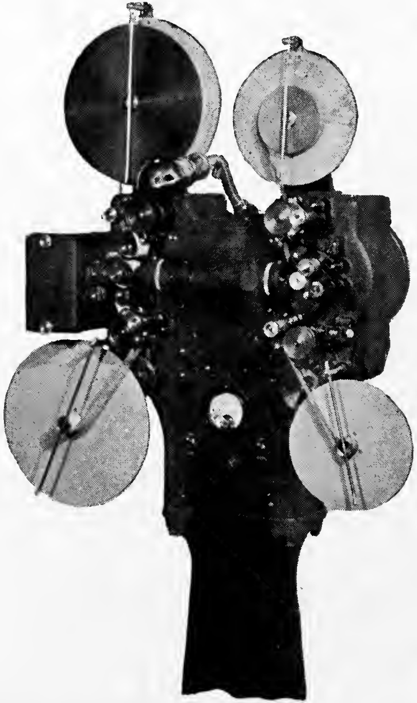


FIG. 11. RCA continuous sound reduction printer.

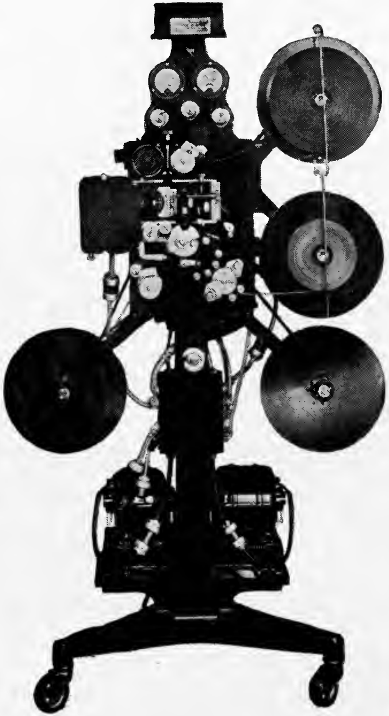


FIG. 12. Depue continuous sound reduction printer.

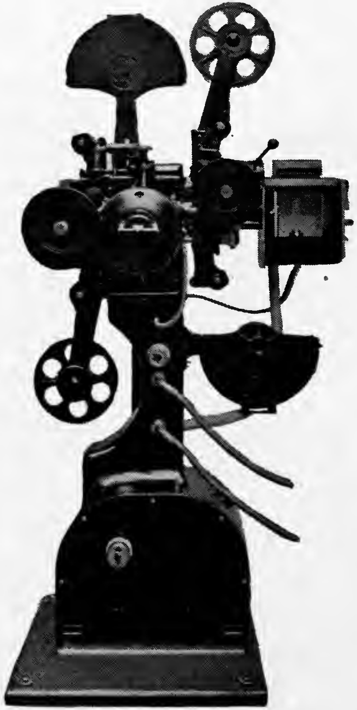


FIG. 13. Debrie Tipro *S;* for reducing 35-mm. to 16-mm. sound-track

(*4*) *Printer Light-Change Systems.*—Each laboratory selects a resistance or a mechanical light-change system according to the advantages that either method may afford under predetermined conditions of laboratory operation. No matter which system is utilized, the laboratory endeavors to maintain the log exposure increments, step for step upon all machines, equivalent in terms of step density value when all printer tests are exposed upon the same piece of film and developed together. Depending upon the number of average scene-changes necessary, resistance boards are employed that will permit making fifty to one hundred and fifty scene-changes during the printing of a 1000-ft. reel of negative. These resistance boards are obviously designed so that at each change of scene any one of the eighteen to twenty-one light-exposure values can be selected. The change of "lights" (as they are customarily termed) from scene to scene is effected by a bar dropping past contact buttons that have been manually set into a surface panel. The bar is moved by a solenoid, the circuit of which is controlled by contacts on notch-feeling rollers riding upon the edge of the negative. The positions of the contact buttons in the panel are chosen by the timer, who assigns the "light" values to the negative to be printed and cuts notches into the edge of the negative where the light-changes are to occur. The printing machine operator puts the contact buttons into place.

The log E change per step of the resistance type of light-control is usually held to such a value that the total change of voltage across the lamp from step *1* to step *18* or *21* will not produce too great a difference of contrast in the print. Change of contrast is due to change of color temperature of the lamp with a change of applied voltage, and, if the variation of color temperature is too great, obviously the change of contrast will be objectionable.

The system of varying the intensity of the light at the printing aperture by mechanical means is well known; and apparently the one most commonly used is the variable shutter-opening type utilized in the Bell & Howell model *D* printer, although the aperture matte system is constantly gaining favor.

(*5*) *Printer Matching* (*Exposure Characteristics*).—Printers are usually matched daily by making a print of a standard negative upon the positive emulsion being used, at a selected step on each printer, and developing the several prints together in a suitable developing system for the time, previously determined, that produces

FIG. 14. Eastman continuous sound reduction printer; 16-mm. side.

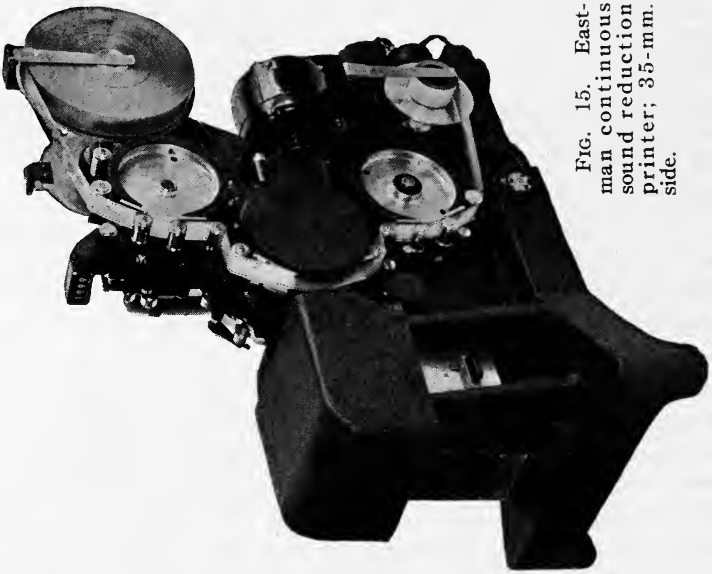


FIG. 15. Eastman continuous sound reduction printer; 35-mm. side.

the correct gamma and print density in a given printer. The step at which the prints are made upon each printer is usually two or three points above the mid-step. If these prints match visually as to density, the printers are then assumed to be matched, step for step, one against the other, upon the basis that all the printers utilize resistance boards having equivalent changes of resistance from step to step, or back shutters having equivalent aperture changes. If a printer is out of match, the fixed aperture opening is increased or decreased until the printer matches the other printers at that step; or the distance of the lamp from the printing aperture may be increased or decreased until the match is attained. Often small adjustable resistances are used in the lamp circuits for balancing the printers. These adjustments are, obviously, made only when the condition of the lamp itself is satisfactory. Frequently, densitometric comparisons of the exposed prints are made, in addition to the visual comparisons. Some laboratories visually, or both visually and densitometrically, compare such strips exposed at every step of each printer every two weeks or every month. In addition to obtaining information as to the matching characteristics of the printers, the uniformity of illumination at the printing aperture is estimated and it is determined whether or not the pressure of the pressure pad is sufficient to maintain firm contact for good definition. This, and all other mechanical details, are usually delegated to the laboratory machine shop. Usually, to determine the uniformity of intensity at the printing aperture, positive film is exposed at a predetermined step, developed, and the uniformity of density over the picture area measured with a densitometer.

The matching of printer sound heads is based upon the same principles, the prints being made from unmodulated sound-track.

(*C*) *System of Printing*

(*1*) *General Practice.*—For timing negatives for making prints, the visual method is used almost exclusively in East Coast laboratories, as it has seemed to be the most practicable and economical since the beginning of the development and printing of motion picture film. With this method the "timer" estimates, according to his experience, the step at which the light-change system of the printer should be set to produce a balanced print scene for scene. Making a balanced print from negatives that have been developed to an approximately constant gamma involves obtaining a series of densities in the various scenes of the print, which has been developed for a predetermined time, such that the print will produce when projected upon the screen, consistent contrast detail in highlights and shadows of the various picture scenes. As the "timer" times (or determines the proper printing steps for) the negative, he usually notches it, cutting a notch into its edge at the fourth frame ahead of the beginning of each light-change for a given scene. The notching is done with a standard negative notching device.

Some laboratories, notably most of those on the West Coast, use a timing machine which makes a print of a section of nine to eleven frames of each negative. A foremost example of such a machine is the "Cinex" timer. Each of the frames receives an exposure that is matched to alternate steps of the printer, so that when the print is developed each of the nine or eleven frames represents the print density that would be obtained by printing with alternate lights, from step *1* to the highest step. The "timer" then visually judges from this print the proper step at which to print the negative so that scenes of balanced density will result throughout given sequences. Whichever system is used, it is the custom for the "timer" to note upon a specially designed timing card the light-step or light-changes for each scene in a given roll of negative. When Cinex tests are made of production negative for the purpose of timing daily prints, the Cinex strips are frequently given to the cameraman on the set so that he can judge the printing quality of his negative.

The sound-track is frequently timed in the same manner, but the practice of timing it by densitometric measurement is growing in favor because the problems of picture composition and detail do not complicate the assignment of printer exposures for sound-track as they do in pictorial work. Both visual and densitometric methods are being used, and as the majority of sound-tracks are re-recorded and therefore balanced for exposure, one light is generally set for printing a complete reel of negative. Variable-density biased negative can be timed correctly only by measuring the unbiased, unmodulated portions of the track.

After the negative picture and negative sound-track have been timed they are given to the operator of the printer with their respective printing cards. From these cards, when resistance boards are used, the light-changes are set up on the board for making the print from the negative, or in the case of standard Bell & Howell continuous printers, the light-changes are made manually as the notched negative trips the circuit interrupter roller. In this case, as the notch trips the roller and changes the light to the manually pre-set point, the operator again manually sets the lever control for the succeeding light-change; whereas, in the case of resistance-board operation, the electrical trip-bar is actuated by the notch-follower roller and automatically sets itself for printing the succeeding scene, according to the sequence established by the set-up of the board.

It is necessary for the printer operator to be sure that the sound-track and the picture start marks are so adjusted in the sound-track and picture apertures that the sound-track will be fifteen and one-half inches ahead of the picture in order that the sound and the picture be synchronous when the print is projected. After the first print is struck off and processed it is projected by the timer, who visually determines whether the proper light-changes have been selected, scene for scene, for the print. If it is necessary to make changes, these light-changes are entered upon the timing cards, and a second print is made with the corrected values. It is often the practice to make as many as four or five trial prints for both picture and sound-track before deciding upon the final printer point settings. Regardless of whether the sound-track negative is entirely re-recorded or there are sections of original recordings in it, the timer projects the print repeatedly and makes printer point corrections for raising or lowering the volume level of the reproduced sound in the various scenes in order to produce the best quality and the most desirable effect. When the print is adjudged as good as can be expected, general release printing from the timed negative is begun. Some laboratories print all release prints from a given reel of negative upon the same printer in order to minimize errors. Similar procedures are followed in making master positives, duplicate negatives, and special types of prints.

(*2*) *Title Making.*—Negative or direct titles are usually made by exposing regular positive emulsions in modified camera mechanisms on special titling stands. On these stands the title cards are mounted upon a special board that is adjustable vertically, horizontally, and rotationally in the vertical plane. The distance between the camera and the easel for holding the title is variable so that cards of different size may be accommodated. The majority of laboratories have designed their own titling apparatus and have taken particular care in its design and construction to assure steadiness of the camera and the easel by mounting them upon a special lathe type bed. In addition, careful consideration has been given to the mechanism to assure accuracy of the focus and steady motion of the film. Various means have been employed for this purpose, such as using very carefully milled registering pins and film edge guides. Because of their actinic power, mercury lamps are generally used as sources of illumination, the type *M* generally being preferred. After titles have been exposed and developed they are timed and printed in a manner similar to timing and printing picture negative and sound-track negative.

Making uniform background titles; illustrated background titles; titles with relief lettering, with either plain or illustrated backgrounds; scroll titles, with either uniform or illustrated backgrounds and with or without relief lettering; and animated titles, are such particular problems and so dependent upon the choice of the producer and the desires of the laboratory that no attempt will be made here to describe the various production technics. For further details regarding making motion picture titles the reader should refer to previous papers by Crabtree and Ives.[3,4]

It is quite general practice in making prints for foreign release to superimpose the foreign-language titles within the picture area, so that the continuity of the sound-track and picture may be maintained. This is usually done by making foreign-language negative titles by standard title-making methods and then spacing the titles with No. *3* leader so that when printed in the picture area they appear synchronously with the English dialog. This system of spacing titles involves splicing No. *3* leader between the titles so that the negative title reel is of the same length as the picture negative reel. This No. *3* leader is a clear support, with no emulsion coating, and is 0.005 inch thick. Some laboratories use News positive film to accomplish this purpose by photographing negative titles sequentially spaced to synchronize with the English dialog. When the News positive film is processed it is ready for use as the superimposing medium, obviating the necessity of using No. *3* leader as spacer. When the foreign release print is made, usually the title negative emulsion faces the emulsion of the raw stock and the picture negative emulsion faces the base of the title negative, so that the three films in contact pass through the picture printing gate at the same time, while the sound-track is printed in the usual manner. Depending upon whether it is best to sacrifice definition of the title or of the picture, the emulsion side of either negative may face the emulsion of the positive raw stock. It has been found more economical in some laboratories to use special types of printers for this purpose. A printer supplied by the André Debrie Company prints the title from a single frame directly upon the picture area simultaneously with the picture negative (Fig. 16). In this type of printer the single-frame title is held in position and

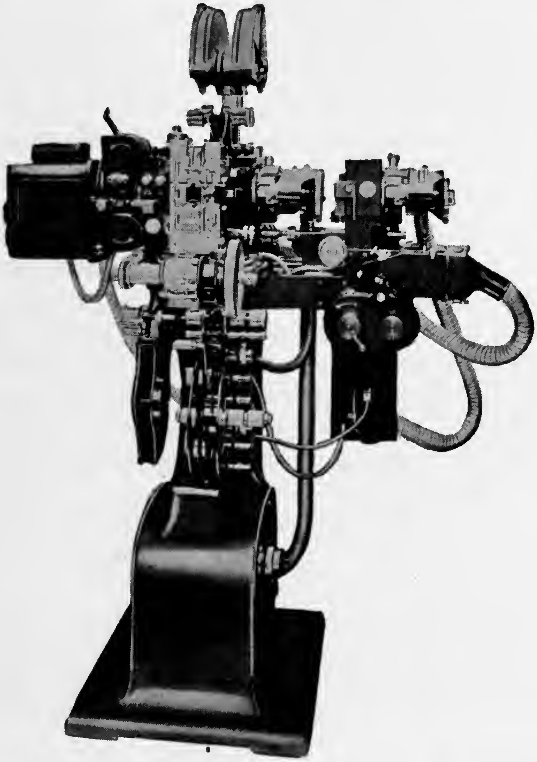


FIG. 16. Debrie Matipo *TU* printer; this printer prints picture, sound-track, and superimposed titles in one operation. Only a single frame of film area is used for each title negative. Insertion of titles and light-changes is fully automatic.

printed in the sequence and for the length of time necessary for reading. One laboratory has constructed its own continuous superimposing or title-inserting printers. They are so designed that automatic stop and start controls for the single-frame title negative can be preset; so that during the printing of a reel of sound-track negative, picture negative, and the single-frame title negative, the titles from the single frame are printed in synchronism with the English dialog, scene for scene, in one operation. The foreign-language titles for use in these printers are made upon a high-contrast photosensitive material, and by means of an ingenious optical system are printed into the picture area from a single frame at the same time the picture negative is printed. It is claimed that the method produces a print in which the title insert and picture have a definition equivalent to what results from printing each negative separately in a continuous printer, and, moreover, that it increases the production rate because it is necessary to make only a single frame of a given title instead of exposing sufficient footage to travel in synchronism with the English dialog during the printing. The laboratories using them contend that these printers afford greater ease in making foreign release prints and a considerable saving in raw stock.

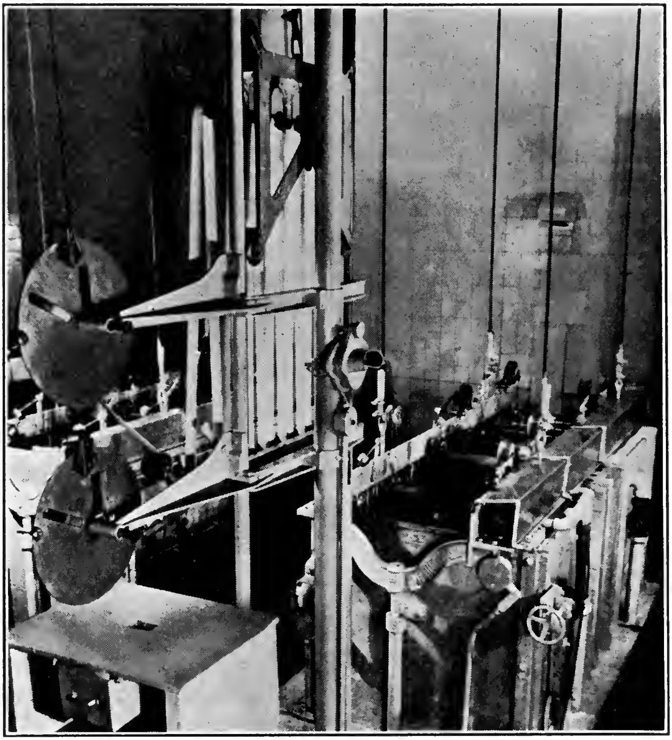
Practically all laboratories have available specially modified commercial printers or printers of their own design for making special effects such as wipe-outs, title inserts, and any kind of trick print desired. These printers are so specialized that it does not seem advisable to describe them, as they vary greatly in type. Furthermore, trick printing is such a specialized art that most laboratories delegate such work to special departments of their organizations.

VI. PROCESSING

(*A*) *Types of Machines*

Continuous machines are now utilized for practically all types of film processing, and rack-and-tank systems are used only where the production output is not sufficient to warrant a continuous machine or when some special effect is desired that can best be handled by the rack-and-tank method.

The operation of a continuous developing machine is fundamentally simple, in that the undeveloped film is fed directly from a feed reel into the machine, or from a feed reel to a feed elevator having sufficient footage capacity at a predetermined speed to allow the feed operator enough time (two to nine minutes) to splice a new roll of film onto the preceding roll so that a continuous band of film will flow continuously through the machine to the take-up reel at the end of the drying cabinet (Figs. 17, 18, and 19). The splices may be either machine-made splices, produced by eyeleting or stapling, or carefully made cement splices. Most of the continuous developing machines are of the roller-rack, deep-tank type, having in the wet section roller-racks parallel to the face of the film as the latter travels through the machine (Fig. 17). Each roller-rack spindle is parallel to the face of the film, and the rack is from six to twelve feet in height and carries from eight to twelve loops of film, depending upon the design of the machine. Usually there are one or two racks in each tank, and the tanks may vary in capacity from 120 to 360 gallons of solution. The racks may be so designed that either all the racks in the wet end of the machine can be lifted vertically completely free of the tanks; or the upper roller-rack may be mounted in a fixed position, and the roller-rack in the lower part of the tank mounted upon a weighted elevator system so that it can be raised until it meets the upper roller-rack. Invariably, in machines in which the film is propelled by power-



(Courtesy of Consolidated Film Industries, Inc.)

FIG. 17. Wet end of Spoor-Thompson continuous developing machine.

driven sprockets, it is necessary that elevators be employed so that the tension of the individual film strands will be independent of the swelling and shrinking of the film. In machines in which the film is propelled through the machine by friction drive only—that is, by frictional contact of the film upon power-driven rollers—there is no necessity for elevators. The film automatically slips forward or backward in accordance with its swell or shrinkage, because the power-driven rollers are always travelling at a slightly greater footage speed than the film and because the tension of the film is such that it will permit slippage.

The upper racks of rollers in the wet end of the machine are generally submerged in the solution so that the film is exposed to the air only on the carry-over loop from tank to tank. Because of specialized design, however, in a number of machines the upper bank of rollers, whether on a rack system at right angles to the long axis of the machine or parallel to the axis, may be from three to eighteen inches above the solution. Usually in each machine there are three or four tanks for development followed by a small loop tank for a rinse wash, three or four tanks for fixing, and five or six tanks for washing. The number of tanks used in the wet end depends upon the lengths of time necessary for the various processes, which in turn depend upon the number of racks in each tank and the footage speed of the machine.

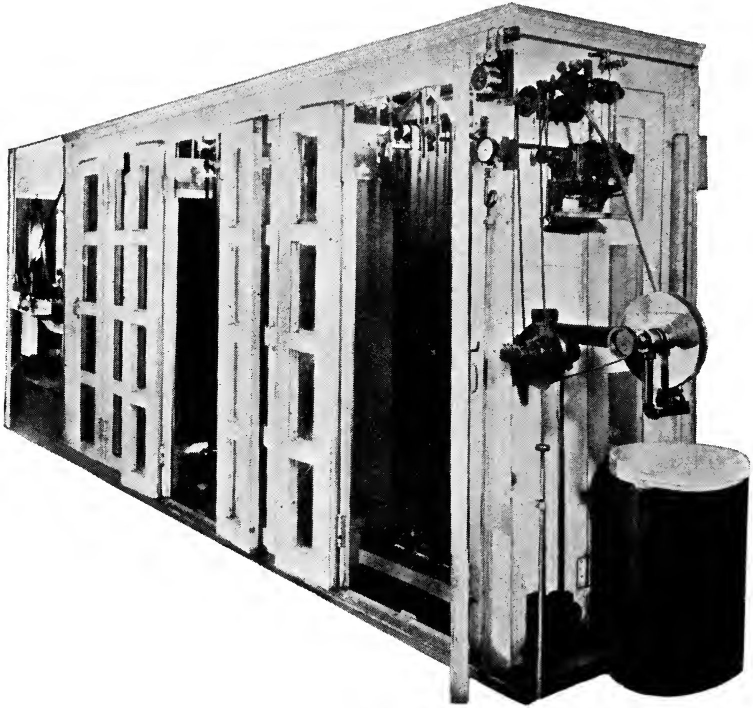
A method for the reduction of "directional effects" in continuous machine developing is gaining favor in a number of laboratories. These effects are caused as the film travels through the machine by the diffusion of development products (oxidation products and bromide salts) from an exposed area of the film into adjacent areas that have had different exposure. The diffusion is counter to the direction of travel of the film, producing a pronounced lower density in areas of film adjacent to and following areas of greater exposure (greater density). The effects are notable on type II*B* sensitometer strips, as different gammas and differently shaped characteristic (*D*-log *E*) curves result from passing the strips through the machine with the heavy or the light exposure areas preceding. The so-called "turbulation" method is said to be satisfactory for minimizing the effect. It consists simply of providing a spray of jets of developer beneath the surface of the developer, impinging directly upon the emulsion surface and causing greater agitation of the solution at the surface of the film.

As the film feeds from the last wash tank of the wet end of the machine into the drying cabinets, it may feed directly or it may pass over a weighted feed elevator. The weighted elevator takes care of the slack, if any, between the drying cabinet and the wet end of the machine, and permits operating either the wet end or the dry end independently of the other. This permits stopping either end of the machine for a short time to take care of troubles that might be caused by mechanical defects or film breakage.

Sometimes the wet end of the machine is in a separate room from the dry end, or both the wet and the dry ends may be in the same room. The first arrangement permits drying in a lighted room and developing in a darkroom, whereas the second requires special illumination of the wet and the dry ends of the machine. Invariably Wratten *OA* Safelights are used for darkroom illumination of the positive developing machines. Wratten Series *III* (green) Safelights are used to illuminate only the dry ends of the negative developing machines because the new fast negative films must be developed in darkness to avoid any slight possiblity of "light fog." The choice of arrangement is dependent upon the desires of the laboratory as to the ease of manipulating the film in the various types of machines.

The drying sections of the machines usually have from five to twenty cabinets, the number depending upon the footage speed of the machine, the volume, velocity, and conditioning of the air; and the type of roller-rack mounting for carrying the film (Fig. 18). The racks in the drying cabinet may be perpendicular or parallel to the axis of the machine. Usually when perpendicular to the axis there are two racks in each cabinet. Like the racks in the wet end of the machine, these racks may carry from eight to twelve rollers per rack, making eight to twelve loops of film, and they are generally from six to seven feet in height so that a man of normal stature can readily reach any section of a loop.

In the majority of drying sections the flow of air is counter to the direction of travel of the film, entering at the bottom of the cabinet and passing out at the top into the top of the preceding cabinet, and so on to the head end of the section. Most laboratories now dry with conditioned and filtered air. There are some, however, that do not have true air-conditioning, in terms of constant temperature and humidity control, because the range of dry-bulb temperature and humidity is dependent to some extent upon atmospheric conditions. Other laboratories have air-conditioning systems



(*Courtesy of Consolidated Film Industries, Inc.*)

FIG. 18. Dry end of Spoor-Thompson continuous developing machine.

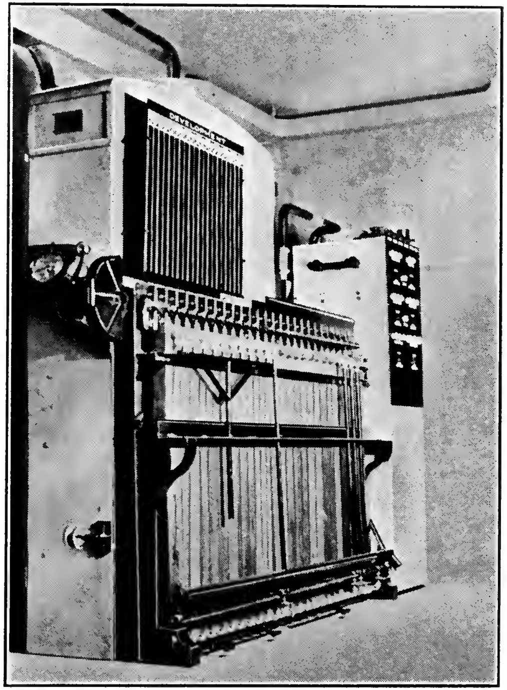


FIG. 19. Debrie small continuous developing machine for either 35-mm. or 16-mm. film.

permitting accurate control over a wide range of wet- and dry-bulb temperatures in addition to allowing special air-conditioning for any complete drying section.

The weight of water remaining in the film after the film has been efficiently squeegeed prior to entering the drying cabinets is a major factor in determining the volume and velocity of air necessary for thorough drying of the film at predetermined wet- and dry-bulb temperatures in a given type of drying section. On the average, positive film contains 1.35 grams or 20 grains and negative film contains 2.0 grams or 30 grains of water per foot of film after squeegeeing (these figures are from data supplied by a national air-conditioning concern). Figures determined by a well known laboratory indicate that the water content of positive film after squeegeeing is about 0.90 gram or 13 grains per foot. Because the type of construction of drying sections varies considerably for different machines and considering also the factors mentioned above, it is impractical to give concrete figures for the volume and velocity of air. Data can be supplied only for specific conditions.

As the film comes from the drying cabinets it is taken up on a rewind reel mounted upon the last drying cabinet or on a special rewind table next to the last drying cabinet. As each machine splice passes from the last drying cabinet it is detected by an automatic trip, or noted by the inspector. The film is then broken and another reel started on the take-up.

The materials used in the construction of continuous motion picture processing machines were described in the JOURNAL by Crabtree, Matthews, and Ross.[5] The recommended materials mentioned in their paper have been used successfully in various laboratory applications.

(B) *Development*

Developer formulas vary greatly from laboratory to laboratory for the development of regular production negative, release prints, master positives, duplicate negatives, titles, and special effects. In general, developer formulas for the development of release prints made on positive film are either the standard Eastman *D-16* formula or a modification of this formula, and the replenisher supply may be of the same formula or a modification of the selected formula that the laboratory technicians believe necessary to give results. Some laboratories derive formulas for the development of positive that bear little or no relation to the *D-16* formula but which still fall within the class of high-contrast developers. Usually laboratories develop all positive types of films in the positive developing system, as it is economically impracticable to maintain machines for slightly varied types of positive materials used for different purposes.

Practically all negative developers are some modification of the Eastman *D-76* borax developer or the Eastman buffered borax developer *D-76d*. Only in a few instances are these developer formulas used in their original concentrations because modifications in concentration are necessary to fulfill the particular conditions in the various laboratories. The properties of the above-mentioned developers and some modifications thereof were described in detail by Carlton and Crabtree.[6] The negative replenisher supply varies in its method of handling, as does the positive replenisher, in accordance with the deductions of the laboratory technicians. In some laboratories the variable-density sound-track negative and the duplicating negative are developed in the same bath as production negative; but most laboratories develop the duplicating negative and the production negative in the same bath, and maintain a separate machine with a suitably tested formula for the development of variable-density sound-track negative. This is often necessary because of the extremely low gamma that the sound-track departments request for variable-density sound-track exposed on sound recording films, which are essentially high-gamma or high-contrast materials. Variable-width sound-track negative (sometimes a special bath is used) and titles are generally developed in the positive bath, and as the attainment of special effects is an art within itself and varies greatly from laboratory to laboratory, the scope of this report does not permit giving these methods in detail. Listed in Tables I, II, and III are several types of positive, negative, and sound-track developers used in various commercial laboratories.

Practically all laboratories have chemical mixing rooms that are either in the basement or upon the top floor of the laboratory building, definitely removed from the printing and developing rooms in order to avoid difficulties from chemical dust spots. In these mixing rooms all solutions are mixed in accordance with standard procedures described in the literature.[7] The quantity of solution mixed depends upon the needs of the laboratory for maintaining sufficient solution for operating for one day to one week. The solutions are mixed in quantities of five hundred to twenty-five hundred gallons, and are

TABLE I

Developer Formulas—Positive Types

Laboratory A

Positive Print and Master Positive Developer, Modified Eastman D-16 Formula

	Original Mix		Replenisher	
Chemical Constituents	Metric	Avoirdupois	Metric	Avoirdupois
Elon	0.30 gram	1 lb. 8 ozs.	0.3 gram	1 lb. 8 ozs.
Sodium Sulfite (desiccated)	40.00 grams	200 lbs.	40.00 grams	200 lbs.
Hydroquinone	6.00 grams	30 lbs.	6.00 grams	32 lbs.
Sodium Carbonate (desiccated)	18.75 grams	93 lbs. 12 ozs.	30.00 grams	160 lbs.
Potassium Bromide	0.90 gram	4 lbs. 8 ozs.		
Water to make	1.00 liter	600 gallons	1.0 liter	600 gallons

Laboratory B

Positive Print and Master Positive Developer, Eastman D-16 Formula

	Original Mix		Replenisher	
Chemical Constituents	Metric	Avoirdupois	Metric	Avoirdupois
Elon	0.30 gram	1 lb. 8 ozs.	0.60 gram	3 lbs.
Sodium Sulfite (desiccated)	40.00 grams	200 lbs.	79.20 grams	396 lbs.
Hydroquinone	6.00 grams	30 lbs.	12.00 grams	60 lbs.
Sodium Carbonate (desiccated)	18.75 grams	93 lbs. 12 ozs.	19.20 grams	96 lbs.
Potassium Bromide	0.90 gram	4 lbs. 8 ozs.		
Citric Acid	0.70 gram	3 lbs. 8 ozs.		
Potassium Metabisulfite	1.50 grams	7 lbs. 8 ozs.		
Water to make	1.00 liter	600 gallons	1.00 liter	600 gallons

Laboratory C

Positive Print and Master Positive Developer

	Original Mix		Replenisher	
Chemical Constituents	Metric	Avoirdupois	Metric	Avoirdupois
Elon	4.80 grams	24 lbs.	4.80 grams	24 lbs.
Sodium	60.0 grams	300 lbs.	60.00 grams	300 lbs.
Hydroquinone	14.40 grams	72 lbs.	14.40 grams	72 lbs.
Sodium Carbonate (desiccated)	21.60 grams	108 lbs.	21.60 grams	108 lbs.
Potassium Bromide	0.80 gram	4 lbs.	0.00 gram	0 lb.
Water to make	1.00 liter	600 gallons	1.00 liter	600 gallons

Laboratory D

Positive Print, Master Positive, and Variable-Width Sound-Track Developer

	Original Mix		Replenisher
Chemical Constituents	Metric	Avoirdupois	
Elon	0.625 gram	3 lbs. 2 ozs.	Same as original mix
Sodium Sulfite (desiccated)	35.000 grams	175 lbs. 0 oz.	
Hydroquinone	3.500 grams	17 lbs. 8 ozs.	
Sodium Carbonate (desiccated)	9.000 grams	45 lbs. 0 oz.	
Potassium Bromide	0.625 gram	3 lbs. 2 ozs.	
Phenosafranine	0.0034 gram	119 grains	
Water to make	1.000 liter	600 gallons	

Laboratory E

Positive Print and Master Positive Developer

Chemical Constituents	Original Mix Metric	Original Mix Avoirdupois	Replenisher
Elon	0.728 gram	3 lbs. 10 ozs.	Same as original mix, less potassium bromide
Sodium Sulfite (desiccated)	21.740 grams	108 lbs. 11 ozs.	
Hydroquinone	3.640 grams	18 lbs. 3 ozs.	
Sodium Carbonate (desiccated)	13.043 grams	65 lbs. 4 ozs.	
Potassium Bromide	0.544 gram	2 lbs. 12 ozs.	
Sodium Hydroxide	0.109 gram	9 ozs.	
Water to make	1.00 liter	600 gallons	

Laboratory F

Positive Print and Master Positive Developer

Chemical Constituents	Original Mix Metric	Original Mix Avoirdupois	Replenisher
Elon	0.30 gram	1 lb. 8 ozs.	Same as original mix, less potassium bromide
Sodium Sulfite (desiccated)	40.00 grams	200 lbs.	
Hydroquinone	6.00 grams	30 lbs.	
Sodium Carbonate (desiccated)	32.00 grams	160 lbs.	
Potassium Metabisulfite	1.50 grams	7 lbs. 8 ozs.	
Citric Acid	0.70 gram	3 lbs. 8 ozs.	
Potassium Bromide	0.90 gram	4 lbs. 8 ozs.	
Water to make	1.00 liter	600 gallons	

TABLE II

Developer Formulas—Picture Negative Types

Laboratory A

Picture Negative, Duplicating Negative, and Variable-Density Sound-Track Negativ Developer

Eastman *D*-76 *d* Buffered Borax Developer

Chemical Constituents	Original Mix Metric	Original Mix Avoirdupois	Replenisher
Elon	2.75 grams	13 lbs. 12 ozs.	Same as original mix
Sodium Sulfite (desiccated)	100.00 grams	500 lbs.	
Hydroquinone	2.75 grams	13 lbs. 12 ozs.	
Borax	8.00 grams	40 lbs.	
Boric Acid	8.00 grams	40 lbs.	
Water to make	1.00 liter	600 gallons	

Laboratory B

Picture Negative and Duplicating Negative Developer

Chemical Constituents	Original Mix Metric	Original Mix Avoirdupois	Replenisher Metric	Replenisher Avoirdupois
Elon	1.35 grams	6 lbs. 12 ozs.	2.70 grams	13 lbs. 8 ozs
Sodium Sulfite (desiccated)	100.00 grams	500 lbs.	240.00 grams	1200 lbs.
Hydroquinone	1.35 grams	6 lbs. 12 ozs.	2.70 grams	13 lbs. 8 ozs
Borax	1.00 gram	5 lbs.	1.95 grams	9 lbs. 12 ozs
Potassium Bromide	0.50 gram	2 lbs.		
Water to make	1.00 liter	600 gallons	1.00 liter	600 gallons

Laboratory C

Picture Negative, Duplicate Negative, and Variable-Density Sound-Track Negative Developer

	Original Mix		Replenisher
Chemical Constituents	Metric	Avoirdupois	
Elon	2.00 grams	10 lbs.	Same as original mix, less potassium bromide
Sodium Sulfite (desiccated)	100.00 grams	500 lbs.	
Hydroquinone	5.00 grams	25 lbs.	
Borax	8.00 grams	40 lbs.	
Boric Acid	8.00 grams	40 lbs.	
Potassium Bromide	0.05 gram	4 ozs.	
Water to make	1.00 liter	600 gallons	

Laboratory D

Picture Negative, Duplicate Negative, and Variable-Density Sound-Track Negative Developer

	Original Mix		Replenisher
Chemical Constituents	Metric	Avoirdupois	
Elon	1.00 gram	5 lbs.	Same as original mix
Sodium Sulfite (desiccated)	90.00 grams	450 lbs.	
Hydroquinone	0.75 gram	3 lbs. 12 ozs.	
Borax	1.00 gram	5 lbs.	
Potassium Metabisulfite	0.50 gram	2 lbs. 8 ozs.	
Water to make	1.00 liter	600 gallons	

Laboratory E

Picture Negative, Duplicate Negative, and Variable-Density Sound-Track Negative Developer

	Original Mix		Replenisher
Chemical Constituents	Metric	Avoirdupois	
Elon	1.00 gram	5 lbs.	Same as original mix
Sodium Sulfite (desiccated)	65.00 grams	325 lbs.	
Hydroquinone	2.50 grams	12 lbs. 8 ozs.	
Borax	1.00 gram	5 lbs.	
Water to make	1.00 liter	600 gallons	

Laboratory F

Picture Negative, Duplicate Negative, and Variable-Density Sound-Track Negative Developer

	Original Mix		Replenisher
Chemical Constituents	Metric	Avoirdupois	
Elon	1.00 gram	5 lbs.	Same as original mix
Sodium Sulfite (desiccated)	100.00 grams	500 lbs.	
Hydroquinone	1.00 gram	5 lbs.	
Borax	1.00 gram	5 lbs.	
Water to make	1.00 liter	600 gallons	

TABLE III

Developer Formulas—Sound-Track Negative Types

Laboratory B

Variable-Density Sound-Track Negative Developer in Use for Regular Production

	Original Mix		
Chemical Constituents	Metric	Avoirdupois	Replenisher
Elon	2.80 grams	14 lbs.	Same as original mix
Sodium Sulfite (desiccated)	100.0 grams	500 lbs.	
Hydroquinone	6.40 grams	32 lbs.	
Borax	4.20 grams	21 lbs.	
Boric Acid	14.70 grams	73 lbs. 8 ozs.	
Water to make	1.00 liter	600 gallons	

Laboratory D

Special Variable-Density Sound-Track Negative Developer

	Original Mix		
Chemical Constituents	Metric	Avoirdupois	Replenisher
Elon	1.0 gram	5 lbs.	Same as original mix
Sodium Sulfite (desiccated)	30.0 grams	150 lbs.	
Hydroquinone	5.0 grams	25 lbs.	
Borax	2.0 grams	10 lbs.	
Boric Acid	8.0 grams	40 lbs.	
Water to make	1.0 liter	600 gallons	

agitated by mechanical stirring devices commonly used for chemical mixing. Usually the solution from the reserve tank is allowed to drip by gravity into the surge tank of the circulating system of the machine. The volume of flow to the surge tank may be manually controlled or controlled by a flow-meter in accordance with the quantity necessary to maintain constant density and gamma for a predetermined developing time. In some laboratories the replenisher supply is periodically added manually to the surge tanks. From the surge tank the developing solution flows either by gravity through a heat interchanger or it may be pumped directly to the machines. Circulating the developer in the machine tanks to the surge tanks and back may be done by pumping and gravity flow or *vice versa*, depending upon whether the surge tank is located above or below the developing machines. Sometimes the replenisher supply of developer is allowed to flow at a predetermined rate directly into the machine at the point at which the film enters. The circulating system generally maintains the temperature constant within ±0.5° to ±1°F. Developers are maintained at temperatures of 65° to 70°F.

(*a*) *Negative Control.*—Methods of sensitometric control in processing motion picture film were ably described by Huse in 1933.[8] In this paper descriptions are given of the methods of using the Eastman

TABLE IV

Fixing and Hardening Baths

Laboratory A

Two-Solution Fixing and Hardening Baths for Negative and Positive Films

Chemical Constituents	Fixing Bath Metric	Fixing Bath Avoirdupois	Hardening Bath Metric	Hardening Bath Avoirdupois
Hypo	518.82 grams	2594 lbs. 2 ozs.		
Sodium Bisulfite	5.23 grams	28 lbs.	5.23 grams	26 lbs. 2 ozs.
Potassium Aluminum Alum			5.23 grams	26 lbs. 2 ozs.
Water to make	1.00 liter	600 gallons	1.00 liter	600 gallons

Laboratory B

Fixing and Hardening Bath for Negative and Positive Films

Chemical Constituents	Metric	Avoirdupois
Hypo	190.00 grams	950.00 lbs.
Potassium Aluminum Alum	3.00 grams	15.00 lbs.
Sodium Sulfite (desiccated)	3.00 grams	15.00 lbs.
Glacial Acetic Acid	7.00 cc.	$4^{1}/_{4}$ gallons
Water to make	1.00 liter	600 gallons

Laboratory C

Fixing and Hardening Bath for Negative and Positive Films (Eastman F-2 Formula)

Chemical Constituents	Original Metric	Original Avoirdupois	Replenisher Metric / Avoirdupois
Hypo	220.00 grams	1100 lbs.	Continuous supply of hypo and hardener under analytical chemical control
Sodium Sulfite (desiccated)	3.0 grams	15 lbs.	
Acetic Acid (28%)	18.00 cc.	$10^{1}/_{2}$ gallons	
Potassium Alum	6.00 grams	30 lbs.	
Water to make	1.00 liter	600 gallons	

Laboratory D

Fixing and Hardening Bath for Negative and Positive Films

Chemical Constituents	Original Metric	Original Avoirdupois	Replenisher
Hypo	400.00 grams	2000 lbs.	Continuous supply of hardener to maintain acidity and uniform hardening
Sodium Sulfite (desiccated)	4.50 grams	22 lbs. 8 ozs.	
Acetic Acid	27.00 cc.	$15^{3}/_{4}$ gallons	
Potassium Alum	9.00 grams	45 lbs.	
Water to make	1.00 liter	600 gallons	

Laboratory E

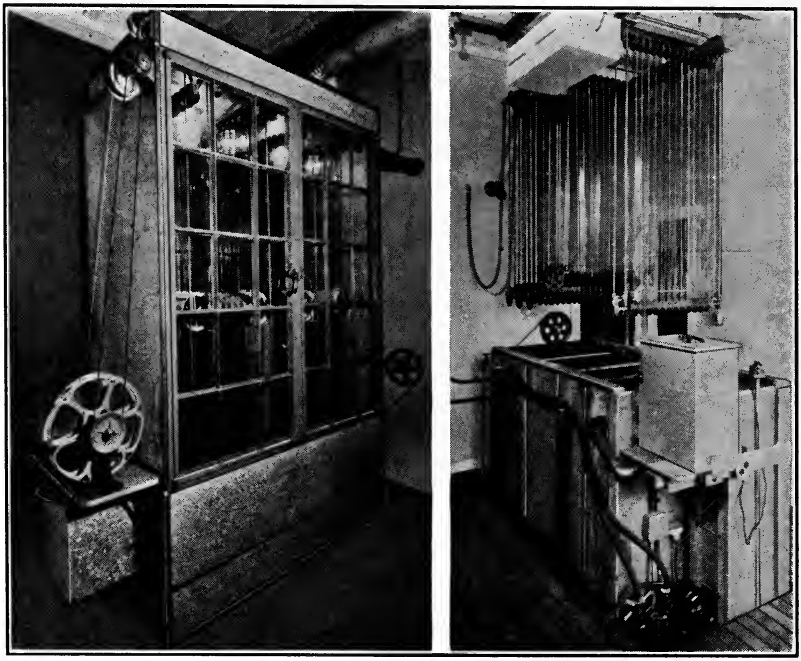
Fixing and Hardening Bath for Negative and Positive Films (Eastman F-25 Formula)

Chemical Constituents	Original Metric	Original Avoirdupois	Replenisher
Sodium Thiosulfate (hypo)	300.00 grams	1500 lbs.	To maintain acidity (*p*H) and uniform hardening, acid and hardener are periodically added to the bath during its useful life
Sodium Sulfite (desiccated)	5.00 grams	25 lbs.	
Acetic Acid, glacial	10.00 cc.	6 gallons	
Boric Acid, crystals	5.00 cc.	25 lbs.	
Potassium Alum	10.00 cc.	50 lbs.	
Water to make	1.00 liter	600 gallons	

Laboratory F

Fixing and Hardening Bath for Negative and Positive Films

Chemical Constituents	Original Metric	Original Avoirdupois	Replenisher
Sodium Thiosulfate (hypo)	300.00 grams	1500 lbs.	To maintain acidity (*p*H) and uniform hardening, acid and hardener are periodically added to the bath during its useful life
Sodium Sulfite (desiccated)	5.00 grams	25 lbs.	
Acetic Acid, glacial	10.00 cc.	6 gallons	
Boric Acid, crystals	5.00 cc.	25 lbs.	
Potassium Alum	10.00 cc.	50 lbs.	
Water to make	1.00 liter	600 gallons	



(*Courtesy of Motion Picture Equipment Co., Ltd.*)

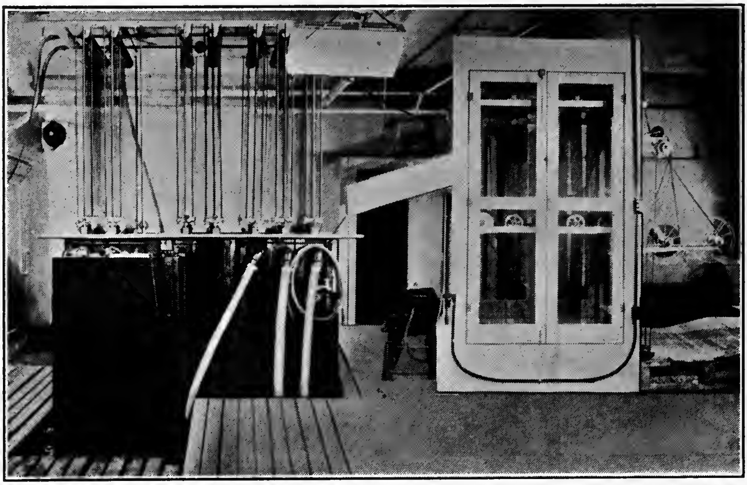
FIG. 20. Artreeves developing machine, showing wet end on the right and dry end on the left.

II*B* sensitometer and the Eastman densitometer as well as explanations of the Hurter and Driffield system of determining the degree of development. Further details are given regarding the meaning and determination of gamma, speed, latitude, and fog values. For more detailed information reference is made to a work by Jones.[1] It therefore does not seem necessary to discuss in detail in this report sensitometric equipment and characteristics of emulsions and developers.

An item of particular importance, however, which should be well understood in the practical application of sensitometry to the control of motion picture film is that a sensitometric strip made under the controlled conditions of time and intensity representing the exposure will give data only as to the degree of development obtained on the particular piece of film exposed. Hence, from a sensitometric strip made on negative motion picture film and developed in a negative bath the laboratory can obtain data that will show only to what definite gamma the negative has been developed; but not information as to the contrast of the picture negative being developed with it, because contrast is a direct function of both the lighting contrast and the film gamma, whether on an outdoor scene or a studio take. The contrast in the negative is a function of the degree of development given the negative, but commercially it is more dependent upon balance of lighting in the shadows and highlights when developed in a controlled developing system. The contrast of the positive, however, can be altered considerably by changing the degree of development, which means decreasing or increasing the gamma of the positive. To convey a clear and concise picture of the control methods in use in the various laboratories, it is less confusing to treat the subjects individually for the control of negative, positive, sound-track, duplicate negative, and duplicate positive films.

There are two different methods of controlling negative development, the choice between which seems to be about equal. One is the constant-time method of development, in which the developing solution is maintained at definite control gamma and density as shown by periodic sensitometric tests, and all original negatives are developed under these standardized conditions. The other method is termed the test-negative method, in which the cameraman furnishes to the laboratory a length of five to fifteen feet each of the various scenes, from which 2- or 3-ft. lengths are clipped and developed for a time that has been predetermined as normal for correct exposures. Following the development of these test-strips, some one (usually the one who supervises negative developing) in the laboratory visually examines the strips and determines the time of development which in his opinion would be best suited for each take or scene to produce the best results upon the screen. In a commercial laboratory, or a laboratory associated with a large production company that has several pictures in the making, the number of test-strips to be made in this manner is considerable; but, in general, all takes made by different cameramen can be developed for the time regarded as normal, whereas the few remaining scenes may vary one-half to several minutes from the normal time. Laboratories using either system feel that each system has its merits, and experience over a period of years has proved that both methods are productive of high-quality results.

When a machine system is started with a new developer, the first problem involves determining what time of development for a constant footage speed, or what footage speed and time of development, will give the desired gamma for a correct exposure. It is general practice to develop a series of strips for slightly different footage speeds or for different times at a constant footage speed, and from the short time-gamma curve so obtained determine the time of development or the footage speed that will give the desired gamma. Once this is established, either system of negative development may be employed as standard for the machine operating under controlled conditions of agitation and temperature of the developing solution. If the laboratory is operating the negative machine on a constant control basis for gamma and density, then all negative is developed for the time or the footage speed that periodic sensitometric tests on the same film as the negative being developed indicate as the correct control gamma.



(Courtesy of Burton Holmes Films, Inc.)

FIG. 21. Continuous developing machine for limited footage output.

To maintain this constant gamma for a fixed time or footage speed of development, sensitometric strips are usually developed every half to one hour, from which data are obtained showing whether the degree of development is greater or less than the original test. The degree of development refers to the constancy of both gamma and density. If the degree of development is less than or greater than the predetermined constants, the replenisher supply is increased or decreased until the proper degree of development is approximated. It is naturally presupposed that the replenisher supply or "boost" developer is so balanced that gamma does not increase as density decreases, or conversely, because a change of such nature would necessitate changing the concentration of chemical constituents in the replenisher to maintain constant gamma and density. Knowledge that has been gained in the laboratories during the past few years has made it a rather simple procedure to determine the rate at which replenisher must be supplied to the developing solutions in the machines to maintain the developer at the predetermined control gamma and density and thereby maintain a uniform degree of development. Depending upon the replenishing system (drip or manual addition) the uniformity of development can be maintained within close limits. Laboratories that utilize rack-and-tank methods have a system of sensitometric control similar to those described above, and by careful manipulative procedure good results are obtained. A survey of various laboratories indicates that at the present time (1935) the average gamma varies among laboratories from 0.60 to 0.75 and that in the majority of cases the control gamma is maintained within ±0.03.

(*b*) *Positive Control.*—In developing regular positive film for release prints, the procedure for sensitometric control of the developing solutions is very similar to that described for negative film. It is of greater importance that a uniform gamma for the positive film be maintained on sound prints than it was when the positive film carried only the picture, because the majority of sound departments specify a definite positive control gamma in order that the sound-track negative gammas can be so maintained as to produce the best quality of sound from the print developed under specified conditions. In addition, the maintenance of a uniform degree of development in the positive developing system is of material assistance to the timer of the negative, as he then is able to ascertain visually with greater ease the printer point difference for various types of negative scenes.

For sensitometrically controlling the positive machines, two or three sensitometered strips exposed on the positive film in use are developed every one-half to two hours in each developing machine of the system, depending upon the requisites of the laboratory. Incidentally, the standardization of a new positive developer in the positive machines is done in the same manner as was described for the standardization of a fresh negative developer. The desired gamma with a given positive developer is obtained by varying the length of time of development by increasing or decreasing the footage speed of the machine or by lowering or raising the weighted elevator system on the racks in the developing tanks. After attaining the desired gamma by one of these methods, the rate of flow of the boost developer into the surge tank or into the developing machine at the point of entrance of the film is regulated in accordance with the footage of positive film passing through the machine. In the event that any general increasing or decreasing trend in the gamma or density is shown by consecutive tests, slight alterations are made either in the time of development or by slightly increasing or decreasing the rate of flow of replenisher. The kind of change to be made is usually recommended by the foreman of the developing room. The procedure described above presupposes that the replenisher is so balanced that gamma does not increase as density decreases, or conversely, because a change of this order would necessitate changing the concentration of the constituents of the replenisher so that gamma and density could be maintained constant for the predetermined rate of replenishment.

Laboratories vary greatly in their ability to maintain constant gamma and density, some endeavoring to control the machine within ±0.05 for gamma and $\pm ^1/_2$ Bell & Howell printer point, which is equivalent to ±5 per cent in terms of log E at a density of unity. This assumes that a Bell & Howell point is equivalent to 0.05 log E, although some laboratories have modified their printer scales to conform to changes as small as 0.025 log E per step. The average laboratory, however, endeavors to maintain a control gamma within ±0.10, and for density $\pm ^1/_2$ to 1 Bell & Howell printer point. A number of laboratories, due to low production schedules and other attendant difficulties, do not hold their controls closer than ±1 Bell & Howell printer point. Positive gammas at present vary, on the average, from 1.9 to 2.3, although some few instances are known in which release prints run as high as 2.4 to 2.5. Often a low or high gamma of the print is purposely maintained because negative from which the print is made has a gamma well below or well above the normal value. Thus the laboratory endeavors in some cases to lower or increase the screen contrast by lowering or increasing the positive gamma of the print made from such a negative.

(*c*) *Sound-Track Control.*—A detailed discussion of the sensitometric control of sound-track development would be exceedingly voluminous, but essentially the control methods are similar to those described for positive and negative film. The two types of sound recording methods most widely used are the RCA Photophone system, which makes use of the variable-width method of recording the sound-track, and the Western Electric System, which makes use of the variable-density method. The laboratory control methods for the two systems will be treated separately, as they differ considerably.

Unless otherwise specified by the customer or the production department at a studio, the laboratory develops and prints variable-width recorded sound-track in accordance with the sensitometric recommendations submitted to their licensees by the RCA Manufacturing Company or any other concern manufacturing sound recording equipment that records a variable-width track.

The engineers of the RCA Manufacturing Company specify at present that in recording with sound recording film in RCA Photophone High-Fidelity equipment the sound-track density shall be 1.40 to 1.50 when the film is developed in a positive type of developer to a control gamma of 2.0 to 2.2. The sensitometric requirements for this specification stipulate that the laboratory determine the time of development of the film being used for the recording to give a gamma within the prescribed limits. It then becomes a simple problem to expose lamp-current tests in the recorder and develop them for this determined developing time, and then select from these tests the proper lamp current to expose the sound-track so that the specified density will be obtained for this development time. Most laboratories readily meet these specifications by developing variable-width track recorded in this manner in the regular positive bath. A few laboratories apparently minimize their control problems by maintaining a separate machine for the development of this type of negative sound-track. The recommendation for the positive track is that the negative be so exposed in the printer that a density of 0.10 to 0.20 below the negative density be obtained when the positive print is developed to a control gamma of 2.0 to 2.2. As most laboratories maintain control gammas of 2.0 to 2.2 for their positive release print developers, this specification is readily met. As an illustration, the sound-track density of the print would be 1.2 to 1.3 if the negative sound-track density were 1.4 to 1.5. Solution control is maintained for negative and positive development during the processing of this type of film in the same manner as was previously described for the sensitometric solution control of the negative developer and the positive developer during release printing. It is the function of the laboratory to maintain the control gammas of both the negative and the positive, and the exposure density value of the positive; whereas it is the function of the recordist to maintain the negative exposure density of negative developed in the developer controlled for gamma and density.

When sound is recorded with the RCA single-film system the combined sound-track and picture negative are developed to a gamma of 0.55 to 0.65, and the sound-track is so exposed that the density approximates 1.3. The print from this negative is so exposed in the printer that the sound-track density approximates 1.1 when the print is developed to a gamma of 2.0 to 2.2. The control system for processing and printing single-system variable-width track of this type is accomplished in a manner similar to the control for negative developing and regular positive release print systems.

The Western Electric system of variable-density recording requires more detailed information for processing the variable-density sound records that utilize the straight-line portion of the H&D curve. The average laboratory develops the sound-track negative in a suitable developer to obtain a gamma of 0.35 to 0.40. Under these conditions the average unbiased, unmodulated negative density ranges from 0.50 to 0.60, this density being controlled by the recordist who adjusts his exposing lamp in accordance with the latitude of the film, which is determined by the points at which the toe and the shoulder break away from the straight-line portion of the characteristic log E curve. This negative is then so exposed in the printer that an unmodulated, unbiased print density of 0.60 to 0.75 will be obtained when the print is developed in the positive picture bath to a control gamma of 2.0 to 2.2. It is necessary that the low negative gamma be obtained to secure an over-all reproduction gamma characteristic approaching the ideal value of unity. This over-all gamma characteristic is determined by plotting projection density as a function of the logarithm of light-valve opening, which is theoretically the same as the product of the positive and negative control gamma multiplied by the projection factor. For ideal results either method should produce a value of unity.

It is the custom of the Western Electric Company or its subsidiary, Electrical Research Products, Inc., to study the entire sensitometric control system from the light-valve (recorder) to the photocell (projector) in any studio or laboratory before making recommendations for processing. The following recommendations regarding Western Electric track control are some general specifications of Electrical Research Products, Inc., in New York City and in Hollywood.

The gamma value resulting from plotting a series of densities obtained by exposing the sound recording film at various light-valve openings as a function of the logarithm of the light-valve opening, is known as the light-valve gamma, $LV\gamma$. The gamma value obtained from the control strip exposed on the type IIB sensitometer and developed with the light-valve gamma strip is known as the negative control gamma, $NC\gamma$. By printing the negative control strip at a predetermined step on the printer and developing this printed strip with the positive sound-track print, a gamma value is obtained which is referred to as the apparent printer gamma, $AP\gamma$. The positive control strip exposed on the type IIB sensitometer developed with this apparent printer gamma strip is known as the positive control gamma, $PC\gamma$.

It is now apparent that the difference in gamma as determined by visual measurement of the diffuse densities and the quasi-specular measurement of the photocell should be determined to assign a correction factor to the above values, as the positive sound-track being scanned during projection has its variation in density read quasi-specularly by the photocell. This factor has been determined for standardized projection conditions and found to be 1.30.

The correct reproduction conditions as recommended by the engineers of Electrical Research Products, Inc., are determined in the following manner:

$$\text{Over-all gamma} = LV\gamma \times AP\gamma \times \text{Projection factor} \tag{1}$$
$$\text{If } LV\gamma = a \times NC\gamma \text{ and} \tag{2}$$
$$AP\gamma = b \times PC\gamma\text{, then} \tag{3}$$
$$\text{Over-all gamma} = NC\gamma \times PC\gamma \times a \times b \times \text{Projection factor} \tag{4}$$

As the factor a, which is the difference between the negative control gamma and light-valve gamma, is found in practice to vary ±5 per cent and the printer factor b varies equally in the opposite direction, factors a and b tend to cancel each other.

After omitting these factors, equation 4 becomes

$$\text{Over-all gamma} = NC\gamma \times PC\gamma \times \text{Projection Factor} \tag{5}$$

Substituting,

$$1 = NC\gamma \times PC\gamma \times 1.30 \text{ or} \tag{6}$$

$$NC\gamma \times PC\gamma = 0.76 \tag{7}$$

According to equation 7, any combination of negative and positive control gammas that will produce a product approximating 0.76 would be correct for straight-line recording. This, of course, is diffuse density gamma.

The laboratories generally follow the specifications from the studio or the recordists as to the negative and positive gammas and unbiased, unmodulated average densities in accordance with these recommendations.

With Western Electric single-system light-valve equipment in which the picture and negative sound-track are exposed on the same film, the negative sound-track is so exposed that an average unmodulated density of approximately 0.65 will be obtained when the negative is developed in the negative picture bath to a control gamma approximating 0.50. If this negative sound-track is not biased it may be re-recorded on sound recording film, and the exposure is made so that an unmodulated density of 0.60 to 0.70 is obtained when the film is developed to a control gamma of 0.45 to 0.50 in either a negative picture developer or a sound-track negative developer. Provided there is sufficient time prior to releasing the newsreels, a print is made from the negative for re-recording which permits balancing volume levels and minimizing distortion. Most single-system recording is done by News organizations and sometimes on distant locations. Formerly prints from news negative were printed to a much higher sound-track transmission than feature release prints so as to give greater volume in the theater, but by mutual agreement the News organizations have now requested that prints be made from these single-system negatives that have the the same volume output at a given fader step as do feature release prints, which means that these prints would have the same specifications as have been previously described for regular release prints.

(*d*) *Master Positive and Duplicate Negative Control.*—It is customary to make the master positive print on a special film known as duplicating positive film and to make the duplicate negative on a special film known as duplicating negative film. The duplicating positive film has an emulsion capable of giving very fine-grained images on full development. A lavender support serves for identification. Some manufacturers offer two grades of contrast in this film to suit the desires of the different laboratories. All duplicating positive is approximately of the same speed as the regular positive film used in making release prints. Duplicating negative film usually has sufficient printer speed so that enough exposure can be obtained through the dense master positive with standard types of printer lamps. This speed, however, is approximately one-fourth to one-sixth that of the master positive or release print positive film. A yellow dye is invariably incorporated in the emulsion of this film that absorbs the wavelengths to which the emulsion is most sensitive. This reduces irradiation or scattering of light, improves definition, and also tends to increase the latitude and lower the contrast of the emulsion.

Precaution is invariably taken to clean the original negative after timing and before printing the master positive, and to clean the master positive after timing and before printing the duplicate negative, because defects are cumulative. Dirt or defects of any kind that are not removed from the original negative or master positive show up in exaggerated form in the print from the duplicate negative. The printing may be done in a continuous or step contact printer or in an optical printer, depending upon which the technician in the laboratory deems the most suitable for obtaining the best duplicates. Often a special printer is selected and used for printing only master positives and duplicate negatives, because uniform illumination and uniform contact at the printing aperture are of the utmost importance to obtain even density and good definition in the final print.

For making the master positive the original negative is timed for the highlights, allowing the shadows to take care of themselves. This usually means that the master positive is printed two to four Bell & Howell printer points heavier, according to the scene, than a print on regular positive film from the same negative. When it is developed in the release print positive developer it has the appearance of a print that is too dense for projection purposes. The increase in density of the master positive above that of the release print varies slightly in different laboratories. The choice of the high- or low-contrast master positive material for printing is based upon the timer's judgment of the contrast of the original negative. The timer therefore decides whether the contrast of the original negative should be increased or reduced during the process of duplication to get the best quality master positive and duplicate negative. If the high- and low-contrast master positive films are developed for the same time as regular positive film in the positive bath, the high-contrast film will give a gamma equivalent to the regular positive used for release printing, whereas the low-contrast film will give a gamma approximately 10 to 15 per cent lower. The master positive is generally developed in the positive bath for the same time as the regular positive film, whether it be the low- or the high-contrast master positive material; but in some laboratories it is believed that slight changes in development improve the quality of the master positive, and consequently this practice is in vogue. Under these conditions the gamma of master positive varies from 1.7 to 1.9 for low-contrast master positive film and from 2.0 to 2.2 for high-contrast master positive film.

As with the master positive, sufficient exposure is given to the duplicate negative to reproduce faithfully every tone and detail of the master positive. Consequently, there are no clear shadows in the duplicate negative even when clear shadows are present in the original negative. The duplicate negative has a tendency to appear somewhat gray, and does not have glassy clear shadows as does the original negative. It is quite general practice to develop the duplicate negative in the picture bath for the time that will produce a gamma equivalent to the gamma of the original negative, which may be from 0.60 to 0.75, but to insure a minimum of graininess the duplicate negative is often developed to a gamma of 0.50 to 0.60. Many laboratories, in the process of duplication, level up the different densities of the various scenes while timing the master positive, so that the duplicate negative can be printed at a single light-setting for all scenes.

The duplication of the sound-track is usually done in a manner similar to that described for picture duplication, with the exception that only a continuous type of printer can be used for the printing. The sound-track, however, is sometimes re-recorded in the customary manner upon sound recording film from a print of the original negative sound-track. Volume levelling and mixing may be done during the re-recording, provided a negative sound-track of better balance than the original can be obtained. The processing of the re-recorded sound-track to be used as a duplicate negative follows the control methods described for continuous machine development of sound-track negative. To reduce the cost and the number of printing and developing operations, it is customary practice in several laboratories to print both the picture and the sound-track negative upon the same strip of master positive film, and then to level up (print) the different densities of the various picture scenes and the sound-track while timing the master positive for printing the duplicate negative upon the same strip of duplicating negative film, so that both the picture and the sound-track can be printed in a single operation at one printer-light setting when making the positive prints. Several laboratories in Hollywood print many of their duplicates in optical printers that are constructed by utilizing a pair of Bell & Howell camera mechanisms. Due to increased contrast obtained by this means, low-contrast duplicating positive materials are used rather than high-contrast.

(*e*) *Specialized Control.*—The sensitometric control for direct or indirect titles, for trick photography, and for all kinds of special effects is a field in which the control methods generally depend upon both the particular studios and laboratories. It is common practice to use regular positive film for making all types of titles, and these are so exposed and developed in the positive picture bath to obtain a maximum of contrast. Some laboratories favor special baths for the development of titles, but the majority of laboratories develop titles for the same time and to the same gamma as the regular release prints. Animated cartoons are generally photographed on panchromatic background negative, and these films are developed in the negative picture bath to give gammas approximating 0.60 to 0.75. The prints from animated cartoon negatives are made in the same manner as are feature release prints, utilizing similar control methods. The processing of trick shots and special effects is so dependent upon the effects desired that the control methods vary greatly from production to production, and consequently it seems inadvisable to attempt to detail the methods in this report. Furthermore, in many studios the Trick and Effects Departments have small laboratory units which they supervise in order to assure rigid control by the effects operators in attaining the desired results.

(*C*) *Fixation and Hardening*

The same type of fixing bath is commonly used for fixing and hardening all kinds of motion picture film. Usually one of the fixing baths recommended by the film manufacturers is utilized, the favored two being the Eastman *F-2* and *F-25* formulas. These formulas and several others in use are listed in Table IV. Chrome alum fixing baths or bisulfite fixing baths are sometimes used because the laboratory technicians believe that these formulas are more efficient and more economical.

The fixation time varies with each type of continuous processing machine in accordance with the design and footage speed. The time of fixation is generally double the time that it takes milkiness of the film to disappear, and on various machines the actual time varies for positive film from four to six minutes and for negative from six to eight minutes. A few laboratories circulate the fixing bath so that the temperature (63° to 68°F.) can be controlled. In others the fixing bath is circulated and replenished periodically with acid hardener. The rate of supply depends upon the results of titration tests to determine acidity and upon melting-point tests on the film to determine the degree of hardening throughout the life of the bath. In the past few years a number of laboratories have installed electrolytic silver recovery systems of the type recommended by the Eastman Kodak Company which offer a means of controlling the uniformity of fixation and hardening, and regeneration of the bath, as well as an efficient means of recovering silver. In laboratories in which no circulation system is employed, or in which a circulation system is employed without connection to a silver recovery system, the bath is replaced as soon as fixing (clearing) the film requires two-thirds of the total fixing time. In some machines, in which two to four tanks are available for fixing, the bath in each tank is pumped consecutively into the preceding tank as it approaches exhaustion, and a new bath is put into the last tank. The exhausted baths are drained to a suitable tank in the basement or outside the laboratory, and the silver is precipitated as silver sulfide by one of the well known sodium sulfide methods. If the recovery tanks are located in the laboratory the exhausted bath is usually neutralized by sodium carbonate or sodium hydroxide, so as to prevent the generation of hydrogen sulfide gas which would cause fogging of the film. The details of the silver recovery methods have been fully described in the JOURNAL.[9]

(*D*) ***Wash Water***

The fresh water supply is usually obtained directly from the city mains except for one known exception in which it is obtained from artesian wells. Before being used for any purpose in the laboratory the water is usually filtered through some type of commercial sand filter to remove suspended vegetable or animal matter that might be present. In some locations the fresh water supply contains a considerable quantity of soluble salts which have sufficient effect upon development and fixation to warrant softening the water used for making up the developers and fixing baths. The water may be so alkaline that it would be impossible to mix a borax type of negative developer unless the water were softened in some manner. Commercial filters using permutite or zeolite, because of their low cost of operation, are in common use for the purpose. So far as is known, no laboratories have water so impure that it can not be used satisfactorily for washing film, but as a precaution the water is generally filtered to remove vegetable and animal matter. The methods of purifying water for use in processing motion picture film are commercial problems, which can be well answered by data appearing in the literature or by firms specializing in water purification systems. The question of purity of water depends upon the nature of the source of the water and the methods by which the water is carried from the source to the point of use. It is obviously a special problem for each laboratory, and often is readily solved by the city sanitary engineer or a consulting engineer.

In most continuous machines the film is washed for fifteen to sixty seconds between development and fixation. The time of washing following fixation varies for positive types of materials from seven to twelve minutes, and for negative types of materials from ten to sixteen minutes. It has been found economical in many instances to use the water from the final wash tank for the rinse between fixation and development. In addition to reducing the consumption of water, this water from the final wash is slightly acidified and therefore acts similarly to an acid stop bath. A number of machines have air squeegees following the rinse bath and following fixation. This prevents dilution and contamination of the fixing bath and avoids carrying over considerable quantities of high-silver-content fixing bath to the final wash water tanks and thus to waste. In laboratories employing electrolytic silver recovery systems or any systems for recirculating the baths for the purpose of regeneration, for the reasons mentioned squeegeeing of some sort is invariably done prior to and succeeding fixation.

Only a few laboratories control the temperature of the wash water systems of their continuous developing machines. The temperature is sometimes roughly controlled by passing the water returning from the interchanger for the developing solution to an interchanger in the water supply line. Usually the temperature of the water in a system of this type will vary from 55° to 65°F. In laboratories that employ no system of cooling, the temperature will vary from 50° to 75°F., and occasionally rises to 80°F.

(*E*) *Drying Conditions*

In all continuous machines the film is squeegeed immediately before entering the drying cabinet or just previously to its entering the elevator system preceding the drying cabinet. Squeegeeing by blowing air at a uniform pressure at an angle of approximately 30 degrees to the film surface from a specially designed wedge slit is favored for removing excess water from the emulsion and support side. In a few machines chamois-covered rollers take the place of air squeegees and act in the manner of ordinary wringers. These procedures prevent water-marks which would otherwise form on the film during drying, and materially reduce the quantity of water that would have to evaporate from the film during the drying process.

The types of air-conditioning systems for drying film, the methods of circulating the air, and the velocity of the air, have been previously described in connection with the design and construction of continuous processing machines. The range of control of the wet- and dry-bulb temperatures varies considerably in the different laboratories, because the requisite conditions for drying the film depend upon the footage speed of the machine, the volume and velocity of the air, the number of cabinets in the drying section, and the type of roller-rack mounting in each cabinet. Dry-bulb temperatures range from 75° to about 120°F., with humidity ranges of 25 to 60 per cent. Most laboratories, however, endeavor to maintain a dry-bulb temperature range of 75° to 85°F., and a wet-bulb temperature that will produce a relative humidity of 35 to 45 per cent. These temperatures and humidities are for processing both positive and negative materials.

It is common practice to develop negative and positive materials in continuous developing machines of the same type. The negative machine, however, is driven at a lower footage speed, to obtain a longer developing time and fewer hazards for the film, and generally the drying end of the negative machine has a larger number of sections than the positive machine, as the negative type film requires longer drying time. All types of positive film developed in positive machines are dried for times varying from fourteen to twenty-two minutes and the negative types from eighteen to thirty-two minutes.

(*F*) *Film Treatment*

It is universal practice to lubricate all prints or treat them for preservation, or both, before shipping them from the laboratory to the exchange. The majority of release prints are lubricated only by waxing the edges with an Eastman edge-waxer or some such suitable device. A number of laboratory technicians, however, favor both lubrication and preservation, in which case the complete emulsion area is treated in some manner in a special machine. Treating the complete emulsion area tends to minimize scratches and abrasions, conditions the flexibility of the film, and also lubricates the surface.

To reduce the handling cost and to increase the speed of production, an edge-waxing device or a solution preserving device is often attached to the end of the last drying cabinet (Fig. 16) so that each print is automatically treated after being dried or during the final drying step prior to passing to the wind-up reel. The edge-waxing device attached to the drying cabinet is similar in design to the Eastman machine in that a solution of wax or oil in carbon tetrachloride is applied by means of two steel disks 0.1 inch thick which partially dip into a reservoir of the solution while the film is led over the disks emulsion side down. The disks track along the perforation webbing of the film. The preserving and lubricating solution is applied by means of a felt-covered steel roller, the width of which is equal to the width of the film, and which partially dips into a reservoir containing the solution while the film is led emulsion side down over the roller. The roller travels in the same direction as the film, at a linear speed considerably less than that of the film, whence the contact of the emulsion with the felt upon the roller has a partial squeegeeing effect so that a maximum quantity of the solution may be applied to the emulsion without running over the perforation edges and the edges of the film. Either of these devices may be used as separately driven equipment for applying either solution while the film is led over the rollers at a speed of approximately 180 feet a minute. Other methods are sometimes used that are regarded more suitable, such as placing ten to twenty 1000-ft. rolls of prints in airtight autoclaves that can be evacuated. Following evacuation a solution containing formaldehyde, an essential oil, and some other ingredients is drawn into the autoclave in an atomized condition for a time of one to two minutes and then the rolls are removed. This treatment is considered to have a lubricating and preserving action on the film.

VII. METHODS OF INSPECTION

Essentially, only two general inspections of film are made, and these apply either to the negatives when received at the laboratory for printing or prior to printing after development, and to the finished prints prior to shipment to the theater or to the exchange. The inspection of negatives and prints will be treated separately, as each requires specialized methods for different purposes.

The present system of controlled development of the high-speed negative materials without safelight illumination prevents inspection of the exposed negative material prior to development, and provided that no trouble has been encountered when exposing the negative in the camera there is no reason for inspection by the laboratory technicians. After the negative has been developed the emulsion and support sides are carefully examined for dirt, scratches, abrasions, spots occurring during development or fixation, moisture marks, *etc.* If any spots classified as removable appear, the film is cleaned with purified carbon tetrachloride or some similar solution before printing. Should there be scratches upon the emulsion side, an attempt may be made to remove them by reprocessing the film, or the film may be sent to one of the firms employing rejuvenation processes for removing or materially reducing the scratches. Usually, however, when such defects occur, the scenes having the deep scratches or abrasions, upon either the emulsion or the base side, are usually retaken. Fine scratches in the base of the film may be removed by polishing, which is done either by spooling the film upon a large drum, emulsion side in, and polishing the base manually with a fine muslin material dampened with a solution of ethyl alcohol (ethyl alcohol denatured with methyl alcohol, Government Denaturing Formula *3A*) and ammonia, or it may be polished by one of the various types of commercial polishing machines using a solution of this type.

Before printing the negative, whether it be a negative developed in the laboratory or received at the laboratory, a careful inspection is made and it is cleaned and polished so that it will be as free as possible from all the above-mentioned defects. It is universal practice to clean the negative after it has been timed for release printing, and to clean it during release printing after every fifth to tenth printing. The cleaning may be done by hand or in a semi-automatic continuous cleaning machine. The choice of the method of cleaning usually depends upon the production problems of the laboratory; however, manual cleaning is generally favored.

The inspection of release prints prior to shipping them to the theaters or exchanges is not as exactingly done as is the inspection of negative materials prior to printing. In some laboratories every print is projection-inspected before shipment, as to sound and picture quality and for the defects mentioned above. As a result of the improvements that have been made in the past few years in laboratory control and methods of manipulation, many laboratories have found it quite satisfactory to inspect by projection only the photographic quality and the presence of defects in the picture, and to inspect audibly every seventh to tenth print to evaluate the sound quality. Sometimes only the fifth to the tenth print is projection-inspected for sound and picture quality during release printing.

VIII. GENERAL AIR-CONDITIONING

It is rarely that a laboratory is completely air-conditioned, perhaps because of the great cost involved. In the past few years air-conditioning firms have found ways and means for making the general air-conditioning of a building much less expensive, and it is believed, therefore, that within a reasonable time more laboratories will have their buildings completely air-conditioned.

In laboratories that are completely air-conditioned, the system has been designed to afford the various wet- and dry-bulb temperatures and humidities in accordance with the requirements of the various parts of the plant. Air-conditioning of the printing rooms and the drying cabinets has been discussed previously under the headings of *Printing* and *Processing.* It is customary in the other rooms of the laboratory to maintain a relative humidity of 35 to 40 per cent with a dry-bulb temperature of 68° to 72°F., which represents a comfortable atmosphere in which to work.

The vaults used for storing valuable motion picture film, whether negative or prints, are usually not air-conditioned but vented with a suitable supply of fresh air. Furthermore, air-conditioning them would be individual problems in most cases because the vaults are generally located in a building separate from the laboratory.

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REFERENCES

[1] JONES, L. A.: "Photographic Sensitometry," *J. Soc. Mot. Pict. Eng.*, Part I, **XVII** (Oct., 1931), No. 4, p. 491; Part II, **XVII** (Nov., 1931), No. 5, p. 695; Part III, **XVIII** (Jan., 1932), No. 1, p. 54; Part IV, **XVIII** (March, 1932), No. 3, p. 324.

[2] HOWELL, A. S., STECHBART, B. E., AND MITCHELL, R. F.: "The Bell & Howell Fully Automatic Sound Picture Production Printer," *J. Soc. Mot. Pict. Eng.*, **XIX** (Oct., 1932), No. 4, p. 305.

HOWELL, A. S., AND MITCHELL, R. F.: "Recent Improvements in the Bell & Howell Fully Automatic Printer," *J. Soc. Mot. Pict. Eng.*, **XXII** (Feb., 1934), No. 2, p. 115.

[3] CRABTREE, J. I.: "The Making of Motion Picture Titles," *Trans. Soc. Mot. Pict. Eng.*, **VIII** (1924), No. 18, p. 223.

[4] CRABTREE, J. I., AND IVES, C. E.: "Improvements in Motion Picture Laboratory Apparatus," *Trans. Soc. Mot. Pict. Eng.*, **VIII** (1924), No. 18, p. 161.

[5] CRABTREE, J. I., MATTHEWS, G. E., AND ROSS, J. F.: "Materials for the Construction of Motion Picture Processing Apparatus," *J. Soc. Mot. Pict. Eng.*, **XVI** (March, 1931), No. 3, p. 330.

[6] CARLTON, H. C., AND CRABTREE, J. I.: "Some Properties of Fine-Grain Developers for Motion Picture Film," *Trans. Soc. Mot. Pict. Eng.*, **XIII** (1929), No. 38, p. 406.

[7] "Elementary Photographic Chemistry," *Eastman Kodak Co.* (Rochester, N. Y.).

[8] HUSE, E.: "Sensitometric Control in the Processing of Motion Picture Film in Hollywood," *J. Soc. Mot. Pict. Eng.*, **XXI** (July, 1933), No. 1, p. 54.

[9] HICKMAN, K.: "Automatic Silver Recovery Control," *J. Soc. Mot. Pict. Eng.*, **XVII** (Oct., 1931), No. 4, p. 591.

BIBLIOGRAPHY

(*All references given below are to the Transactions or* JOURNAL *of the Society of Motion Picture Engineers, unless indicated otherwise. Dates prior to January, 1930, refer to the Transactions, at which time the Transactions were discontinued and replaced by the* JOURNAL.)

LAYOUT OF A PROCESSING LABORATORY

BRIEFER, N. M.: "Problems in Motion Picture Laboratories," **VI** (1922), No. 15, p. 51.

ROTHACKER, W. R., AND ALLER, J.: "Problems of the Film Processing Laboratory," **VII** (1923), No. 16, p. 120.

LINDSAY, D. C.: "Air-Conditioning as Applied in Theaters and Film Laboratories," **XI** (1927), No. 30, p. 334.

SHEA, T. E.: "A Modern Laboratory for the Study of Sound Picture Problems," **XVI** (March, 1931), No. 3, p. 277.

CRABTREE, J. I., MATTHEWS, G. E., AND ROSS, J. F.: "Materials for the Construction of Motion Picture Processing Apparatus," **XVI** (March, 1931), No. 3, p. 330.

MANHEIMER, J. R.: "Some Aspects of the National Electrical Code as Applied to the Motion Picture Industry," **XV** (Aug., 1930), No. 2, p. 145.

Report of the Sub-Committee on Laboratory Practice, **XX** (March, 1933), No. 3, p. 183.

HISTORY OF RAW STOCK

FOWLER, E. W., AND NEWELL, L. B.: "Storage and Handling of Motion Picture Film," **XVI** (June, 1931), No. 6, p. 773.

METHODS OF COMPARING EMULSIONS

JONES, L. A.: "Photographic Sensitometry," Part I, **XVII** (Oct., 1931), No. 4, p. 491; Part II, **XVII** (Nov., 1931), No. 5, p. 695; Part III, **XVIII** (Jan., 1932), No. 1, p. 54; Part IV, **XVIII** (March, 1932), No. 3, p. 324.

CAPSTAFF, J. G., AND GREEN, N. B.: "A Motion Picture Densitometer," **VII** (1923), No. 17, p. 154.

CAPSTAFF, J. G., AND PURDY, R. A.: "A Compact Motion Picture Densitometer," **XI** (1927), No. 31, p. 607.

CRABTREE, J. I., AND IVES, C. E.: "A Trial-and-Error Method of Preparing a Motion Picture Sensitometer Tablet," **XI** (1927), No. 32, p. 740.

JONES, L. A.: "A Motion Picture Laboratory Sensitometer," **XVII** (Oct., 1931), No. 4, p. 536.

HUSE, E.: "Sensitometric Control in the Processing of Motion Picture Film in Hollywood," **XXI** (July, 1933), No. 1, p. 54.

CHAMBERS, G. A., AND WRATTEN, I. D.: "The Eastman Type II*B* Sensitometer as a Control Instrument in the Processing of Motion Picture Film," **XXI** (Sept., 1933), No. 3, p. 218.

EICH, L. F.: "A Physical Densitometer for Sound Processing Laboratories," **XXIV** (Feb., 1935), No. 2, p. 180.

PRINTING

VICTOR, A. F.: "The Continuous Reduction Printer," **III** (1919), No. 9, p. 34.

DEPUE, O. B.: "A Daylight Optical Reduction Printer," **X** (1927), No. 28, p. 242.

HITCHINS, A. B.: "Duplex Optical Printers," **XI** (1927), No. 32, p. 771.

GREGORY, C. L.: "An Optical Printer for Trick Work," **XII** (1928), No. 34, p. 419.

DEPUE, O. B.: "Machinery for Making Duplicate Negatives," **XII** (1928), No. 36, p. 1170.

DEPUE, O. B.: "A Printer for Simultaneous Printing of Sound and Picture Negatives," **XIII** (1929), No. 37, p. 150.

VAUGHN, W. S., AND TUTTLE, F.: "Curved Gates in Optical Printers," **XIV** (June, 1930), No. 6, p. 663.

NORLING, J. A.: "Automatic Focusing Devices for Title and Cartoon Cameras," **XII** (1928), No. 36, p. 1088.

STORY, W. E., JR.: "Actinic Measurements on the Exposing and Printing of Motion Picture Film," **V** (1921), No. 13, p. 106.

JONES, L. A., AND CRABTREE, J. I.: "A New Sensitometer for the Determination of Exposure in Positive Printing," **VI** (1922), No. 15, p. 89.

JONES, L. A.: "Printing Exposure and Density in Motion Picture Positives," **VI** (1922), No. 15, p. 102.

IVES, C. E., MILLER, A. J., AND CRABTREE, J. I.: "Improvements in Motion Picture Laboratory Apparatus," **XVI** (Jan., 1931), No. 1, p. 26.

BUTTOLPH, L. J.: "Cooper-Hewitt Neon Lamps," **XII** (1928), No. 34, p. 557.

HOWELL, A. S., STECHBART, B. E., AND MITCHELL, R. F.: "The Bell & Howell Fully Automatic Sound Picture Reduction Printer," **XIX** (Oct., 1932), No. 4, p. 305.

CRABTREE, J. I., AND IVES, C. E.: "A Trial-and-Error Method of Preparing a Motion Picture Sensitometer Tablet," **XI** (1927), No. 32, p. 740.

NORLING, J. A., AND LEVENTHAL, J. F.: "Some Developments in the Production of Animated Drawings," **X** (1926), No. 25, p. 58.

NORLING, J. A.: "Automatic Focusing Device for Title and Cartoon Cameras," **XII** (1928), No. 36, p. 1088.

COLLINS, M. E.: "RCA *PB-141* Optical Reduction Printer." Presented at the Fall, 1935, Convention at Washington, D. C.; to be published in a forthcoming issue of the JOURNAL.

DEPUE, O. B.: "A Machine for Printing Picture and Sound Simultaneously and Automatically," **XVIII** (May, 1932), No. 5, p. 643.

WOOD, R. V.: "A Shrinkage Compensating Sound Printer," **XVIII** (June, 1932), No. 6, p. 788.

HOWELL, A. S., AND MITCHELL, A. F.: "Recent Improvements in the Bell & Howell Fully Automatic Printer," **XXII** (Feb., 1934), No. 2, p. 115.

VICTOR, A. F.: "Continuous Optical Reduction Printing," **XXIII** (Aug., 1934), No. 2, p. 96.

BATSEL, C. N.: "A Non-slip Sound Printer," **XXIII** (Aug., 1934), No. 2, p. 100.

DIMMICK, G. L., BATSEL, C. N., AND SACHTLEBEN, L. T.: "Optical Reduction Sound Printing," **XXIII** (Aug., 1934), No. 2, p. 108.

CHAMBERS, G. A.: "Process Photography," **XVIII** (June, 1932), No. 6, p. 782.

HINELINE, H. D.: "Composite Photographic Processes," **XX** (April, 1933), No. 4, p. 283.

CRABTREE, J.: "Sound-Film Printing," **XXI** (Oct., 1933), No. 4, p. 294.

BATSEL, C. N., AND SACHTLEBEN, L. T.: "Some Characteristics of 16-Mm. Sound by Optical Reduction and Rerecording," **XXIV** (Feb., 1935), No. 2, p. 95.

PROCESSING

MITCHELL, W. M.: "Applications of Stainless Steels in the Motion Picture Industry," **XXIV** (April, 1935), No. 4, p. 346.

FOOTE, R. L.: "Laminated Bakelite in the Motion Picture Industry," **XXIV** (April, 1935), No. 4, p. 354.

LA QUE, F. L.: "Inconel as a Material for Photographic Film Processing Apparatus," **XXIV** (April, 1935), No. 4, p. 357.

LEAHY, W.: "Time and Temperature *vs.* the Test System for Development of Motion Picture Negatives," **XVIII** (May, 1932), No. 5, p. 649.

KOSSMAN, H. R.: "A Small Developing Machine," **XXIII** (Dec., 1934), No. 6, p. 356.

RUSSELL, H. D., AND CRABTREE, J. I.: "An Improved Potassium Alum Fixing Bath Containing Boric Acid," **XXII** (Aug., 1933), No. 2, p. 137.

MEYER, H.: "Sensitometric Studies of Processing Conditions for Motion Picture Films," **XXV** (Sept., 1935), No. 3, p. 239.

SILENT, H. C., AND FRAYNE, J. G.: "Western Electric Noiseless Recording," **XVIII** (May, 1932), No. 5, p. 551.

KÜSTER, A., AND SCHMIDT, R.: "The Sensitometric Control of Sound Records on Film," **XIX** (Dec., 1932), No. 6, p. 539.

FAULKNER, T.: "The Treatment of New Film Prior to Release," **XIX** (Nov., 1932), No. 5, p. 419.

SHEA, T. E.: "A Modern Laboratory for the Study of Sound Picture Problems," **XVI** (March, 1931), No. 3, p. 277.

MATTHEWS, G. E., AND ROSS, J. F.: "Materials for the Construction of Motion Picture Processing Apparatus," **XVI** (March, 1931), No. 3, p. 330.

STEWART, V. A.: "Improvements in Laboratory Practice," **XI** (1927), No. 32, p. 651.

CRABTREE, J.: "Uniformity in Development," **XXV** (Dec., 1935), No. 6, p. 512.

CLARK, W.: "Standard Development," *Photo. J.*, **65** (Feb., 1925), No. 2, p. 76.

BULLOCK, E. R.: "On Convection Effects in Photographic Bathing Processes in the Absence of Agitation," *Brit. J. Phot.*, **69** (1922), No. 3225, p. 110.

NIETZ, A. H.: "Theory of Development," Monograph No. 2, *Kodak Research Labs., Eastman Kodak Co.*, Rochester, N. Y. (1922).

MEES, C. E. K., AND PIPER, C. W.: "Fogging Powers of Developers," *Phot. J.*, **52** (May, 1912), No. 5, p. 221.

SHEPPARD, S. E., AND ELLIOTT, F. A.: "Influence of Stirring on Rate and Course of Development," *J. Franklin Inst.*, **195** (Feb., 1923), No. 2, p. 211.

CRABTREE, J.: "Directional Effects in Continuous Film Processing," **XVIII** (Feb., 1932), No. 2, p. 207.

CRABTREE, J., AND WADDELL, J. H.: "Directional Effects in Sound-Film Processing—II," **XXI** (Nov., 1933), No. 5, p. 351.

RENWICK, F. F.: "A Preliminary Note on the Development of Motion Picture Film," **VII** (1923), No. 16, p. 159.

CRABTREE, J. I.: "The Development of Motion Picture Films by the Reel and Tank Systems," **VII** (1923), No. 16, p. 163.

HUBBARD, R. C.: "Erbograph Machine—a Friction Feed Developing Machine for Developing Positive Motion Picture Film," **VII** (1923), No. 17, p. 163.

HUBBARD, R. C.: "The Straight-Line Developing Machine," **VIII** (1924), No. 18, p. 73.

CRABTREE, J. I., AND DUNDON, M. L.: "Investigations on Photographic Developers—Sulfide Fog by Bacteria in Motion Picture Developers," **VIII** (1924), No. 19, p. 28.

CRABTREE, J. I.: "The Handling of Motion Picture Film at High Temperature," **VIII** (1924), No. 19, p. 39.

HITCHINS, A. B.: "Machine Development of Negative and Positive Motion Picture Films," **IX** (1925), No. 22, p. 46.

CRABTREE, J. I., AND IVES, C. E.: "Racks and Airbell Markings on Motion Picture Film," **IX** (1925), No. 24, p. 95.

CRABTREE, J. I., AND DUNDON, M. L.: "The Staining Properties of Motion Picture Developers," **X** (1926), No. 25, p. 108.

HICKMAN, K. C. D.: "Syphons and Measuring Devices for Photographic Solutions," **X** (1926), No. 26, p. 37.

CRABTREE, J. I., AND DUNDON, M. L.: "Investigations on Photographic Developers," **X** (1926), No. 26, p. 111.

KELLEY, W. V. D.: "The Examination of Film by Projection on a Continuous Processing Machine," **XI** (1927), No. 3, p. 224.

SHEPPARD, S. E.: "Behavior of Gelatin in the Processing of Motion Picture Film," **XI** (1927), No. 32, p. 707.

HUNTER, C. R.: "A Negative Developing Machine," **XII** (1928), No. 33, p. 195.

JAMIESON, H. J.: "A Horizontal Tray Type of Continuous Processing Machine," **XII** (1928), No. 36, p. 1093.

DUNDON, M. L., AND CRABTREE, J. I.: "The Fogging Properties of Developers," **XII** (1928), No. 36, p. 1096.

CARLTON, H. C., AND CRABTREE, J. I.: "Some Properties of Fine-Grain Developers for Motion Picture Film," **XIII** (1929), No. 38, p. 406.

MOYSE, H. W., AND WHITE, D. R.: "Borax Developer Characteristics," **XIII** (1929), No. 38, p. 445.

DUNDON, M. L., BROWN, G. H., AND CAPSTAFF, J. G.: "A Quick Test for Determining the Degree of Exhaustion of Developers," **XIV** (April, 1930), No. 4, p. 389.

HUSE, E.: "Sensitometric Control in the Processing of Motion Picture Film in Hollywood," **XXI** (July, 1933), No. 1, p. 54.

MACKENZIE, D.: "Straight-Line and Toe Records with the Light-Valve," **XVII** (Aug., 1931), No. 2, p. 172.

CAPSTAFF, J. G., AND SEYMOUR, M. W.: "The Duplication of Motion Picture Negatives," **X** (1927), No. 28, p. 223.

IVES, C. E., AND HUSE, E.: "Notes on Making Duplicate Negatives," **XII** (1928), No. 34, p. 382.

"The Duplication of Motion Picture Negatives," *Eastman Kodak Co.*, Rochester, N. Y.

MEES, C. E. K.: "Some Photographic Aspects of Sound Recording," **XXIV** (April, 1935), No. 4, p. 285.

COFFMAN, J. W.: "Sound-Film Processing," **XII** (1928), No. 35, p. 799.

MAURER, J. A.: "The Photographic Treatment of Variable-Area Sound-Films," **XIV** (June, 1930), No. 6, p. 636.

CRABTREE, J. I., AND HART, H. A.: "Some Properties of Fixing Baths," **XIII** (May, 1929), No. 38, p. 364.

CRABTREE, J. I.: "The Handling of Motion Picture Films at High Temperatures," **VIII** (1924), No. 19, p. 39.

CRABTREE, J. I., AND ROSS, J. F.: "Silver Recovery from Exhausted Fixing Baths," **X** (1926), No. 26, p. 70.

HICKMAN, K., WEYERTS, W., AND GOEHLER, O. E.: "Electrolysis of Silver-Bearing Thiosulfate Solutions," *Ind. and Eng. Chem.*, **25** (Feb., 1933), p. 202.

HICKMAN, K., SANFORD, C., AND WEYERTS, W.: "The Electrolytic Regeneration of Fixing Baths," **XVII** (Oct., 1931), No. 4, p. 568.

CRABTREE, J. I., AND RUSSELL, H. D.: "Some Properties of Chrome Alum Stop Baths and Fixing Baths," **XVI** (May, 1930), No. 5, p. 483; Part II, **XVI** (June, 1930), No. 6, p. 667.

WEYERTS, W. J., AND HICKMAN, K. C. D.: "The Argentometer—an Apparatus for Testing for Silver in a Fixing Bath," **XXV** (Oct., 1935), No. 4, p. 335.

HICKMAN, K. C. D.: "Washing Motion Picture Film," **IX** (1925), No. 23, p. 62.

CRABTREE, J. I., AND MATTHEWS, G. E.: "Effect of the Water Supply in Processing Motion Picture Film," **XVI** (April, 1931), No. 4, p. 437.

CRABTREE, J. I., AND MATTHEWS, G. E.: "A Study of the Markings on Motion Picture Film Produced by Drops of Water, Condensed Water Vapor, and Abnormal Drying Conditions," **VII** (1923), No. 17, p. 29.

WHITE, D. R.: "Drying Conditions and Photographic Density," **XIX** (Oct., 1932), No. 4, p. 340.

NORLING, J. A., AND RIPPENBEIN, A. P.: "Treatment for Rejuvenating and Preserving Motion Picture Film," **XVI** (June, 1931), No. 6, p. 766.

METHOD OF INSPECTION

FAULKNER, T.: "Cleaning Motion Picture Positive Film," **X** (1926), No. 25, p. 117.

CRABTREE, J. I., AND CARLTON, H. C.: "Cleaning Liquids for Motion Picture Film," **XI** (1927), No. 30, p. 277.

DWORSKY, A. S.: "The Dworsky Film Renovating Machine, Polishing Machine and Film Rewind," **XI** (1927), No. 32, p. 774.

CRABTREE, J. I., AND IVES, C. E.: "Rack Marks and Airbell Markings on Motion Picture Film," **IX** (1924), No. 25, p. 25.

CRABTREE, J. I., AND MATTHEWS, G. E.: "Oil Spots on Motion Picture Film," **XI** (1927), No. 32, p. 28.

CRABTREE, J. I., AND DUNDON, M. L.: "The Staining Properties of Motion Picture Developers," **X** (1926), No. 25, p. 108.

GENERAL AIR-CONDITIONING

LINDSY, D. C.: "Air-Conditioning as Applied in Theaters and Film Laboratories," **XI** (1927), No. 30, p. 343.

HOLDEN, E. C.: "Silica Gel Air-Conditioning for Film Processing," **XVIII** (April, 1932), No. 4, p. 471.

RAPID PROCESSING METHODS*

H. PARKER AND J. I. CRABTREE**

Summary.—*The properties of various developers, including a two-bath hardening developer suitable for the rapid processing of negatives, are described. In the case of still photography, considerable time can be saved by printing from the wet negatives. Several methods are described for holding the negative to prevent damage to the wet emulsion by the heat of the printer light.*

With the increasingly widespread use of photography, situations are occurring more and more frequently when it is desired to obtain the finished photograph in as short a time as possible after the negative is exposed. In the past, this situation has often arisen in news photography, but with the more recent applications of photography as, for instance, in such fields as television, the photographic recording of the finish of horse races, and, in motion picture work, for production stills and test shots on projected background scenes, the need for rapid processing is becoming more and more important.

Most of the published procedures for rapid photography involve the use of quick-acting developers and fixing baths of more or less conventional composition, followed by a brief wash. The print is then made directly from the wet negative or after the negative, which was hardened during processing, has been dried rapidly.

The rapid drying may be accomplished either by directing blasts of warm, dry air against both faces of the film, by removal of the water by means of a volatile solvent such as alcohol, or by absorption of the water with a suitable strong solution having an affinity for water, such as a saturated solution of potassium carbonate. The treatment with alcohol is not recommended for use with film, since methyl alcohol attacks the film base, tending to make it curl and buckle upon drying. Ethyl alcohol can be used successfully, provided that (*a*) the film is not bathed in the alcohol for too long a period which would otherwise cause buckling; (*b*) that the alcohol is diluted with 10 per cent of water; and (*c*) that the film is finally

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** Eastman Kodak Co., Rochester, N. Y.

dried with air at a temperature not greater than 70° to 80°F. The use of undiluted alcohol and air which is too hot causes excessive desiccation of the gelatin which renders it opalescent. The opalescence can be removed by soaking the film in water and re-drying slowly.

When the emulsion is dehydrated with a saturated solution of potassium carbonate, traces of the carbonate are left in the gelatin so that if the relative humidity is very low it may crystallize, while with high humidity the negative remains sticky. Also, it is necessary to rewash and dry the negative in the usual manner after the rush prints have been made. It is safer and more satisfactory, therefore, to dry the negatives with hot air.

A satisfactory, rapid processing procedure should fulfill the following requirements:

(*1*) In order to reduce to a minimum the time required for making up the baths, they should be in the form of stock solutions ready to use with very little measuring, mixing, or diluting.

(*2*) In order to save the time required for cooling the solutions, it should be possible to use them over a range of temperature at least from 65° to 80°F.

(*3*) In order to lessen the danger of mechanical injury to the emulsion and to allow rapid drying with hot air, the solutions should not have a great tendency to swell the emulsion and should harden it thoroughly.

(*4*) Photographically, any rapid method, to be satisfactory, should give good picture quality with high emulsion speed, since underexposure is very apt to be encountered.

The three processing methods to be described meet these specifications quite well, each method having some specific advantages under certain conditions.

Two-Bath Development with Developer SD-6.—For the majority of cases, a rapid two-bath hardening developer[1] is satisfactory since it prevents excessive swelling, provides rapid and thorough hardening of the gelatin while in the developer, and allows the use of comparatively high processing temperatures. Also, it automatically eliminates the danger of overdevelopment and provides an almost constant degree of development in spite of variations in the time of treatment which can otherwise easily occur in hand processing for such short times.

The film is placed in the bath No. *1*, whereupon the emulsion absorbs a certain quantity of the solution and thus a definite quantity of the developing agents, but because of the low alkalinity of the solution, very little actual development occurs. Then, when the film is placed in the alkaline bath No. *2*, development proceeds rapidly at first, but since the developing agents diffuse out from the film, after a short time the development practically stops. The result is that considerable variation in the times of treatment have very little effect upon the degree of development.

Also, the separation of the developer chemicals into two baths makes it possible to use formalin, which gives a rapid and high degree of hardening in alkaline solutions while avoiding the troublesome reactions that otherwise occur between formalin and the developing agents in a single-bath developer, which tend to reduce the rate of development and often cause bad aerial fog and stains.

The formulas for the two-bath *SD-6* developer solutions are given in the section on practical recommendations. Sodium sulfate is used in the first bath to prevent excessive swelling of the gelatin emulsion before it can be hardened by the formalin in the second bath. The small quantity of phenosafranine is a safeguard against the formation of aerial fog which might otherwise occur if, during treatment, the film were exposed much to the air. A portion of the formalin in the second bath reacts with the sulfite, liberating sodium hydroxide, so it is not necessary to add any additional alkali. The two solutions used to prepare bath No. *2* slowly deteriorate when mixed and, therefore, the bath must be used within a short time after it has been mixed, but the separate solutions keep well before mixing.

The film should be bathed for 1 minute in bath No. *1;* then, without rinsing, transferred to bath No. *2* and kept thoroughly agitated therein for 1 minute, taking care not to expose the emulsion surface to the air, otherwise aerial fog is apt to be produced. In the case of sheet film it is convenient to hold the film by one corner with a film clip in order to facilitate handling and allow thorough agitation. After development, the film should be rinsed briefly, preferably in an acid stop bath *SB-1*, and then fixed, with thorough agitation to insure neutralization of the alkali in the film and to hasten fixation. As soon as the film has cleared, it can be washed and dried or printed wet, as described later.

The *F-5* hardening fixing bath gives excellent results when used after this developer but, if desired, an ultra-rapid non-hardening bath may be used. In the latter case, it is particularly desirable to rinse in the acid stop bath between development and fixation.

Since development is almost complete soon after the film has been placed in bath No. *2*, the degree of development can not be controlled effectively by varying the time of treatment in the second bath. If a desired degree of contrast is not obtained by normal treatment, development can be altered slightly, say, over the gamma range from 0.6 to 0.7 with Supersensitive Panchromatic film at 75°F., by changing the time of treatment in the first bath. If a greater increase in the contrast is desired, it can be readily obtained by reimmersing the negative in bath No. *1* for a short time after rinsing briefly in water to remove the excess of solution carried upon the surface of the film.

When used in tray development, these solutions are not affected by aerial oxidation as rapidly as are equally energetic single-bath developers, because the developing agents are held in a weakly alkaline solution and are well protected by the sulfite, while the separate solution containing the alkali contains no developing agents. When a negative is developed, it carries a small quantity of the developing agents into the second bath, but the concentration resulting from this action is low so there will be no danger of staining the film even if the developing agents are oxidized.

Although this sytem of development is particularly designed for use at high temperatures, it can be used satisfactorily over quite a range of temperature, from 65° to 85°F. Below 65°F., the degree of development is probably too low to be useful, while above 85°F. there is danger that the emulsion will swell excessively. The rate of change of activity with temperature is lower for this developer than for the more usual single-bath developers. For instance, with Eastman Supersensitive Panchromatic cut film at 75°F., a gamma of 0.65 was obtained equal to that given by developing for 1 minute in full-strength *D-72*, but when both developers were cooled to 65°F., the two-bath developer gave a gamma of 0.50 while the gamma obtained in the *D-72* had dropped to 0.40. In both cases the two-bath developer *SD-6* gave noticeably more shadow detail than the *D-72*.

The characteristics of this developer with Eastman Supersensitive Panchromatic cut film (July, 1935) are given in Table I. It will be noticed that the two-bath developer compares favorably with other developers for the lower degrees of contrast, but that it does not compare so well when development is forced in order to obtain high contrast or the highest possible emulsion speed.

Other Rapid Developers.—In Tables I and II are also given the development characteristics of several rapid single-bath developers for short times of development. The values listed are: gamma, which is a measure of the degree of development; fog; relative emulsion

TABLE I

Development Characteristics of Rapid Developers with Eastman Supersensitive Panchromatic Cut Film (July, 1935) at 65°F.

Developer	Time (Minutes)	Gamma	Fog	Relative Emulsion Speed* (Per Cent)	Highlight Density
D-82	1	0.57	0.12	85	0.73
D-82 + caustic	1	1.00	0.15	105	1.33
D-9	1	0.55	0.10	90	0.70
D-9 + formalin	1	0.52	0.12	70	0.63
D-8	1	1.29	0.12	35	1.04
D-72	1	0.40	0.12	65	0.50
D-82	2	0.83	0.12	125	1.15
D-82 + caustic	2	1.35	0.21	125	1.88
D-9	2	0.89	0.12	110	1.19
D-9 + formalin	2	0.81	0.14	75	0.98
D-8	2	1.49	0.15	60	1.54
D-72	2	0.70	0.13	85	0.96
Two-Bath at 75°F. (1st Bath)	1				
		0.65	0.15	105	0.91
(2nd Bath)	1				
D-82	3	1.01	0.17	130	1.45
D-82 + caustic	1	1.00	0.15	105	1.33
D-9	$2^{1}/_{2}$	1.02	0.14	110	1.40
D-9 + formalin	3	1.00	0.17	75	1.20
D-8	40	1.00	0.11	30	0.75
D-72	$3^{1}/_{2}$	1.02	0.17	100	1.30
Two-Bath (1st Bath)	1				
(2nd Bath)	1	1.00	0.25	105	1.35
(1st Bath)	$1^{1}/_{2}$				

* The relative emulsion speeds are expressed in percentages, the speed obtained by developing for $3^{1}/_{2}$ minutes in *D-72* (gamma 1.0) being taken as 100 per cent.

TABLE II

Characteristics of Developers Suitable for Underexposures (Times of Development for Optimum Emulsion Speeds)

Developer	Time (Minutes)	Gamma	Fog	Relative Emulsion Speed	Highlight Density
D-82	8	1.20	0.40	155	2.04
D-82 + caustic	3	1.50	0.40	145	2.25
D-9	9	1.45	0.40	150	2.25
D-8	6	1.60	0.40	115	2.30
D-72	14	1.33	0.40	120	2.07

speed, which is a comparative measure of the ability of the emulsion to render shadow detail; and highlight density, which is a rough indication of the density contrast obtained in a normally exposed negative of a subject of average contrast. It must be remembered that these are the values found under a given set of conditions as to quantity of developer, size of film, agitation during development, and so on, and that they will vary if any of these conditions are altered. However, although the absolute values will vary, the relations between the different developers will change very little if at all. It should also be noted that the indicated speed ratings are on a purely arbitrary basis, and are not directly related to the speed systems used with the various exposure calculators and exposure meters. The ratio factor necessary to convert these values to the system used with any given device can be determined from a test with some one developer, such as the *SD-6* two-bath, or the *D-72*. The recorded data are for Supersensitive Panchromatic cut film, but the relations between the various developers are approximately the same for other panchromatic negative materials.

TABLE III

Time-Temperature Characteristics of D-72 Developer

Temperature	Time of Development				
65°F.	1 Min. 30 Sec.	2 Min.	2 Min. 30 Sec.	3 Min.	4 Min.
70°F.	1 Min. 15 Sec.	1 Min. 40 Sec.	2 Min.	2 Min. 30 Sec.	3 Min. 15 Sec.
75°F.	1 Min.	1 Min. 20 Sec.	1 Min. 40 Sec.	2 Min.	2 Min. 40 Sec.
80°F.	50 Sec.	1 Min. 5 Sec.	1 Min. 20 Sec.	1 Min. 40 Sec.	2 Min. 10 Sec.
85°F.	40 Sec.	55 Sec.	1 Min. 5 Sec.	1 Min. 20 Sec.	1 Min. 45 Sec.
90°F.	33 Sec.	45 Sec.	55 Sec.	1 Min. 5 Sec.	1 Min. 25 Sec.

The developers listed fall into two classes, those suitable for hand processing, and those which are suitable only for ultra-rapid development in special processing machines. These very rapid developers are not suitable for hand processing because the development times must be so short, in order to avoid excessive contrast, that there is not time to obtain uniform development over the whole surface of the film.

When the processing is done by hand, under the conditions mentioned previously, that is, where temperatures above normal may be encountered with no time available for cooling the solutions, the *D-72* developer and the *D-9* process developer with 1 per cent of formalin added, have been found very satisfactory.

In most cases, the *D-72* developer is probably preferable, since it can be used for plates, films, and papers. Also, it is more stable and oxidizes only slowly even when left standing in a tray.

This developer has a temperature coefficient of, roughly, 1.5 for a temperature change of 10 Fahrenheit degrees. This means that to get approximately equal degrees of development at different temperatures, the development time must be divided by 1.5 for a 10-degree rise in temperature, and multiplied by 1.5 for a 10-degree drop in temperature. A time-temperature table is given in Table III.

This developer has a sufficiently high concentration of salts to prevent excessive swelling up to 80°F. but it does not permanently harden the film, so that an efficient hardening fixing bath must be used and the film fixed long enough to allow it to harden thoroughly. The *F-5* fixing bath may be used at normal temperatures, but at the higher temperatures the *F-23* chrome alum hardening fixing bath should be used and the film treated for at least 3 minutes and preferably longer. With the chrome alum bath, particularly, there is danger that scum may form upon the film from the neutralization of the fixing bath by the developer, so that the film should be rinsed for a few seconds in an acid stop bath, such as the *SB-1*, after development, and then agitated thoroughly while it is in the fixing bath. Fresh fixing solutions should always be used for this work. The chrome alum fixing bath has the objection that it does not keep well, so it should be made up in small quantities which can be used up in a few days.

In cases where temperatures higher than 80°F. must be used, the *D-72* developer, even in combination with the chrome alum fixing bath, is not satisfactory. In such cases the *D-9* caustic-hydroquinone process developer may be used with the addition of 10 cc. of formalin (40 per cent solution) per liter of the mixed developer to harden the film. Ten cc. of a 1 to 1000 solution of phenosafranine should also be added to prevent the formation of aerial fog which might be caused by the formalin. This developer, as the tables show, has a slightly higher rate of development than the *D-72*, so the times given above, or somewhat shorter times, may be used. This developer has poor keeping properties after it is mixed and should be used immediately. The *F-5* fixing bath gives good results with this developer although an ultra-rapid fixing bath can be used, as with the two-bath developer. This developer gives good results at temperatures up to 90°F. but can not be used satisfactorily at temperatures above 90°F.

It can be seen from the data given in the table that this addition of formalin to the *D-9* developer causes a slight increase in the development fog, a slight decrease in the emulsion speed, and a very slight decrease in the rate of development.

More complete information on regular processing methods (not rapid processing) at high temperatures is given elsewhere.[2]

Ultra-Rapid Developers for Machine Processing.—When it is possible to develop by machine as, for instance, with motion picture film, it is sometimes desirable to obtain high densities in very short times of development. With machine processing the treatment of the film can be controlled much more uniformly than is possible with hand processing, and it is quite satisfactory, therefore, to use very short times and very active developers.

A considerable number of developer formulas have been tested to determine their usefulness with very short development times and the data obtained for the most satisfactory formulas are given in the tables. These results show that when good contrast, with the greatest emulsion speed (ability to reproduce shadow detail), is desired in a very short time of development (1 minute or less), formula *D-82* with the addition of 10 grams per liter of sodium hydroxide gives the most satisfactory results. This addition of extra sodium hydroxide to the *D-82* developer causes a very considerable increase in the rate of development, so that considerably higher gammas are obtained. For the very short times of development, higher emulsion speeds are also obtained. It should be noted, however, that for the longer times of development, or for comparisons made at equal gammas, this advantage is lost, and the unmodified *D-82* gives just as high emulsion speeds. For very short development times, around 30 seconds or less, it may be desirable to add 25 cc. of ammonia per liter to the modified *D-82* developer. This addition is not satisfactory when development times of 1 minute or longer are used, because of the very rapid growth of fog, but for the very short times, it does help to obtain higher emulsion speeds. When the highest possible contrast is desired, the *D-8* developer may prove more useful, but it should be noted that for a given exposure and equal times of development the *D-8* does not give as high a density as the *D-82* with the extra sodium hydroxide, for, although it gives a higher gamma, it gives a much lower emulsion speed. When a high contrast is undesirable, but it is wished to obtain high emulsion speed without excessive density in the highlights, the *D-82* and the *D-9* developers give better results than the two higher-contrast developers.

While all these developers give much more rapid development at higher temperatures, it is definitely unsafe to use them at high temperatures because of the danger of excessive swelling of the gelatin film.

Developers for Underexposures.—The practical value of a developer for treating extreme underexposures is determined by the minimum exposure value which the developer is capable of differentiating from the development fog under the optimum conditions of development. Experience has shown that for Supersensitive Panchromatic film treated in these high-energy developers, the optimum rendering of shadow detail is obtained when the development is continued until the fog has a density of approximately 0.3 to 0.4. If the development is forced beyond this point, the fog begins to increase more rapidly, so that it tends to obscure some of the shadow detail. As can be seen from Table II, which gives the data for several developers, the gammas obtained at these optimum times of development range between 1.20 and 1.60. Under these conditions of development, formulas *D-9*, *D-82*, and *D-82* with added sodium hydroxide give practically equally satisfactory rendering of detail in the extreme shadows, while *D-72* gives somewhat less detail in the shadows, and *D-8* still less. This is illustrated graphically in Fig. 1 which shows the relative appearance of negatives on Supersensitive Panchromatic cut film which had been given graded exposures and then developed for the optimum times as shown in Table II. It can be seen that the strips developed in *D-82*, *D-82* with added caustic, and *D-9* show from one to two more steps in the extreme shadows than the strips developed in *D-8* and *D-72*. Since each step corresponds to a decrease of approximately 20 per cent in the exposures, this indicates an increase of 25 to 40 per cent in the effective emulsion speed, which is approximately the increase shown in the table.

Rapid Fixing.—The rate of fixation as measured by the time required to clear the film of undeveloped silver salts, depends upon a number of factors, the most important of which are: hypo concentration, degree of exhaustion of the bath, temperature, and degree of agitation. For low concentrations of hypo, the clearing time is decreased as the concentration is increased, reaching a minimum for Eastman Supersensitive Panchromatic film at a concentration of about 360 grams per liter of hypo. If the hypo concentration is raised above this value, the clearing time again increases. For rapid work, therefore, extra hypo should be added to the usual fixing bath formula to bring the total hypo concentration to 360 grams per liter (3 pounds per gallon).

When a fixing bath is used, a number of changes occur which tend to increase the clearing time. Therefore, fresh fixing solution should always be employed. The temperature of the bath has a considerable effect, higher temperatures giving more rapid fixing, but on prolonged storage at high temperatures the bath is apt to sulfurize. The *F-5* fixing bath can be used up to 75°F., while for processing at much above this temperature, the *F-23* chrome alum hardening fixing bath should be used. Thorough agitation of the film in the fixing bath decreases the clearing time considerably, as it helps to wash away the dissolved silver salts and supply fresh hypo to the emulsion. Since agitation also helps to prevent the formation of a scum upon the emulsion surface, it should not be neglected.

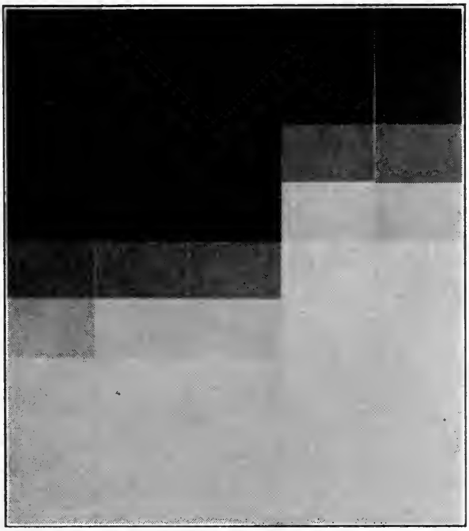

FIG. 1. Appearance of step tablet exposures on Supersensitive Panchromatic cut film, showing relative effect of various developers in the underexposure region, when developed for times to give optimum emulsion speeds.

If a still shorter fixing time is desired, an improvement can be obtained by the addition of about 25 grams per liter ($3^1/_4$ ozs. per gallon) of ammonium chloride. If much more than this quantity is added, the clearing time will be increased, but this quantity gives a decrease, particularly if the hypo concentration happens to be a little low. The addition of ammonium chloride seems to be most effective with a non-hardening bath such as the *F-24* with increased hypo, but it also has some effect with hardening baths such as the *F-5*.

For rapid processing, fixation may be considered to be sufficiently complete as soon as the milky appearance has disappeared from the emulsion. The processing is completed by washing the film for 2 minutes in a rapid stream of water and drying with blasts of warm air directed against both sides of the film. To hasten the drying and prevent the formation of water marks upon the film, all drops of surface water should be removed by wiping both sides of the film with a piece of absorbent cotton, chamois leather, or viscose sponge which has been thoroughly wetted and then squeezed as dry as possible by hand.

FIG. 2. Holder for printing from wet negatives on cut film.

After the prints have been made, the negative should be returned to the fixing bath for 5 or 10 minutes, then washed thoroughly and dried in the usual manner, otherwise there will be danger of fading of the image if the negatives are to be kept for any length of time.

Methods of Printing.—If desired, the time required for drying the film can be saved by making the prints from the wet negative. If only one enlargement is required, and the enlarger lamp house is adequately cooled, the usual method of sandwiching the film between two sheets of glass can be used, although it may be necessary to use a few drops of glycerine between the film and each sheet of glass to help exclude air bubbles. However, if more than one or two prints are required, this method is not satisfactory because the glass becomes heated under the printer light, and tends to soften the emulsion, melting it or making it stick to the glass.

These difficulties can be avoided by the use of a special holder.

FIG. 3. The Eastman processing frame, which allows cut films to be handled like plates during processing and enlarging.

The one shown in Fig. 2, which grips the negative only by the edges, is very satisfactory and convenient to handle, or the Eastman processing frame, illustrated in Fig. 3, which is designed to hold cut films so that they may be handled and processed like plates, may also be used to hold the film during printing. In either case, the excess water drops must be carefully removed from the surfaces of the film by wiping with moist absorbent cotton, chamois leather, or viscose sponge. When the processing frame is used, the water should be shaken as completely as possible from the grooves of the frame before the film is wiped and care exercised thereafter to prevent shaking more water drops out upon the surface of the film.

Another useful device, though it can be used only with a horizontal enlarger, is shown in Fig. 4. This is a very thin liquid cell made of two sheets of glass clamped by the metal frame to a *U*-shaped separator cut from soft sheet rubber. The cell is large enough to receive the negative and just thick enough (1 to 2 mm.) to allow the film to slide in freely. The frame should grip the glass sides just tightly enough to hold them firmly, but not tightly enough to cause any strains. It may be necessary to soften the surfaces of the rubber separator by moistening with benzene just before assembling the cell in order to make the joints water-tight. The cell is filled with water which has been boiled to free it of dissolved air, or it can be filled with fixing bath or hypo solution. In the latter case, it is unnecessary even to rinse the film after fixing, since the liquid in the cell will then have almost exactly the same density and index of refraction as the liquid remaining on and in the film after treatment in the fixing bath. Since the cell may become quite hot if a large number of prints are made, the solution used in the cell should not have a tendency to sulfurize easily. Plain acid baths such as the *F-24* fixing bath give very satisfactory service, even when ammonium chloride has been added to give very rapid fixing.

In most projection printers and enlargers there is rather inadequate provision for cooling the lamp house, and the negatives are subjected to considerably more heat than is necessary. In most cases, considerable cooling can be effected by providing forced ventilation with compressed air. If the negative is held in a water cell, the air blast may be thrown against the cell to cool it directly, but the greatest advantage is obtained from the general cooling of the lamp house. For direct protection of the negative from the radiant heat of the lamp, a water cell similar in construction to the negative holder but about one inch thick, or a piece of heat-absorbing glass, such as the Aklo Heat Resisting Glass made by the Corning Glass Works or, better, a combination of both, should be placed between the lamp and the negative. If desired, the heat-absorbing glass can be used to form one side of the cell.[3] Such a combination will absorb almost all the infrared or heat radiation which would otherwise heat the negative, without noticeably affecting the visual or the photographic intensity of the light.

If the liquid cell is used alone, it is more effective to use, instead of plain water, a 5 per cent solution of copper sulfate or a 2 per cent solution of cupric chloride[4] which absorbs practically all the infrared radiation. If the printer is to be operated more or less continuously, some provision should be made for removing the heat absorbed by the liquid. This can be accomplished by circulating the liquid through some type of cooling coil. If plain water is used in the cell, this can be cooled by circulating through an automobile hot-water heater, the blower fan serving to pull cooling air through the radiator coils.

The General Electric Company has produced a special high-intensity lamp[5] which has a water cell built completely around the bulb. The end of this water jacket contains a cooling coil through which tap water is circulated to carry away the heat, while distilled water is used in the jacket to insure highest transmission for the visible light. This lamp can be installed readily in the enlarger, the only requirement being that the lamp be used in a vertical position with the base up.

FIG. 4. Thin water cell for holding wet cut films in the enlarger.

If a water cell is undesirable, a sheet of heat-absorbing glass may be used alone. In this case, the glass should be adequately cooled to remove the heat absorbed. This can be done by forced ventilation around the glass.

PRACTICAL RECOMMENDATIONS

For convenience, the foregoing recommendations are summarized briefly, and the formulas of the various solutions used are given below.

Two-Bath Development.—The two-bath developer (Formula *SD-6*) provides for thorough hardening of the emulsion during development, it may be used at temperatures from 65° to 85°F. (best results are obtained at 75° to 80°F.), and it gives a fairly constant degree of development in spite of variations in the development time. The solutions are stable and are not readily oxidized even when standing in trays. The negative should be placed for 1 minute in the first bath, then transferred to the second bath without rinsing, and treated for 1 minute with agitation, taking care not to expose the film unnecessarily to the air in order to avoid aerial fog.

If this treatment does not give sufficient contrast, the negative can be rinsed for 1 or 2 seconds and returned to the first bath for 15 to 30 seconds or longer, as desired. This developer is not recommended, however, in cases where it is necessary to obtain the highest contrast or the highest possible emulsion speed.

After development the film should be rinsed for a few seconds in water or an acid rinse bath, and fixed in the *F*-5 fixing bath. It may then be washed briefly in running water and dried rapidly with warm air blasts (conveniently obtained with small electric hair dryers), or it may be placed in one of the holders described, and printed from while wet.

RAPID TWO-BATH DEVELOPER
(Formula *SD-6*)

First Bath

	Avoirdupois	Metric
Water (about 125°F.) (52°C.)	24 ounces	750.0 cc.
Elon	44 grains	3.0 grams
Sodium sulfite (desiccated)	365 grains	25.0 grams
Hydroquinone	88 grains	6.0 grams
Sodium sulfate (desiccated)	3 ozs. 145 grains	100.0 grams
Sodium carbonate (desiccated)	290 grains	20.0 grams
Water to make	32 ounces	1.0 liter

Dissolve the chemicals in the order given.

Second Bath

Solution *2A*	Avoirdupois	Metric
Phenosafranine (1:1000 sol.)	5 drams	20.0 cc.
Sodium sulfite (desiccated)	1 oz. 290 grains	50.0 grams
Potassium bromide	30 grains	2.0 grams
Water to make	32 ounces	1.0 liter

Solution *2B*

Formalin (40 per cent solution)	6½ fluid ozs.	200.0 cc.
Water to make	32 ounces	1.0 liter

To make the second bath, mix equal parts of solutions *2A* and *2B*.

ACID RINSE BATH
(Formula *SB-1*)

	Avoirdupois	Metric
Water	32 ounces	1.0 liter
Acetic acid (28 per cent, pure)	1½ fluid ozs.	48.0 cc.

ACID HARDENING FIXING BATH
(Formula *F-5*)

	Avoirdupois	Metric
Water (about 125°F.) (52°C.)	20 ounces	600.0 cc.
Sodium thiosulfate (hypo)	8 ounces	240.0 grams
Sodium sulfite (desiccated)	½ ounce	15.0 grams
Acetic acid (28 per cent, pure)	1½ fluid ozs.	47.0 cc.
Boric acid, crystals	¼ ounce	7.5 grams
Potassium alum	½ ounce	15.0 grams
Cold water to make	32 ounces	1.0 liter

When rapid fixing is desired, it is preferable to increase the hypo concentration to 12 ounces in 32 ounces (360 grams in 1 liter).

Single-Bath Development.—If the solutions for the two-bath developer are not available, the *D-72* developer may be used full strength, developing about 2 minutes at 65°F. The solution may be used up to 80°F., with the development time reduced accordingly. After development the film should be rinsed for about 5 seconds in an acid rinse bath and fixed for 3 minutes or longer in the *F-23* chrome alum fixing bath with thorough agitation, especially during the first minute (at temperatures below 75°F., the *F-5* fixing bath may be used).

If the film is not agitated when placed into the chrome alum fixing bath, a greenish white scum of basic chromium sulfite may be deposited upon its surface. This should be removed by swabbing the wet film with moist absorbent cotton, since it is very difficult to remove it after the film has been dried. Its formation can be prevented by rinsing and agitating the film properly.

The use of a hardening rinse bath is not recommended, because the time available for treatment in the rinse bath is only a few seconds, much too short for any effective hardening action.

ELON HYDROQUINONE DEVELOPER

(Formula *D-72*)

	Avoirdupois		Metric
Water (about 125°F.) (52°C.)	16	ounces	500.0 cc.
Elon	45	grains	3.1 grams
Sodium sulfite (desiccated)	1½	ounces	45.0 grams
Hydroquinone	175	grains	12.0 grams
Sodium carbonate (desiccated)	2¼	ounces	67.5 grams
Potassium bromide	27	grains	1.9 grams
Water to make	32	ounces	1.0 liter

Dissolve the chemicals in the order given.

CHROME ALUM FIXING BATH

(Formula *F-23*)

Solution *A*	Avoirdupois		Metric
*Sodium thiosulfate (hypo)	2	pounds	960.0 grams
Sodium sulfite (desiccated)	1	oz. 290 grains	50.0 grams
Water to make	96	ounces	3.0 liters
Solution *B*			
Water	20	ounces	600.0 cc.
Sodium sulfite (desiccated)	290	grains	20.0 grams
Sulfuric acid, 5%	5	fluid ozs.	160.0 cc.
Potassium chrome alum	4¼	ounces	128.0 grams
Water to make	32	ounces	1.0 liter

Dissolve the constituents of *A* and *B* and cool both to 70°F. (21°C.). Add *B* slowly to *A* while stirring the latter thoroughly.

* More rapid fixation may be obtained by using 2½ lbs. of hypo per gallon (1200 grains per 4 liters) instead of the quantity given in solution *A*.

Development at Higher Temperatures.—With the two previous methods of development, if the room temperatures are very high, it is necessary to cool the solutions to about 80°F. If this is not desirable, the *D-9* caustic process developer with the addition of 1 per cent formalin may be used at temperatures up to 90°F. The development time should be 1½ to 2 minutes at 65°F., and less at higher temperatures. After development the film should be rinsed for about 5 seconds in an acid rinse bath, and fixed until it has cleared in the *F-5* fixing bath.

The proper development time at any temperature can be determined from Table III, if the time which gives the desired degree of development at 65°F. is known. Although the temperature coefficients of the other developers vary slightly, this table is sufficiently accurate for use with any of the developers mentioned in this paper, except the two-bath developer, for which the times need not be changed over the temperature range from 65° to 85°F.

CAUSTIC PROCESS DEVELOPER

(Formula *D-9*)

Stock Solution *A*	Avoirdupois	Metric
Water (about 125°F.) (52°C.)	16 ounces	500.0 cc.
Sodium bisulfite	$^3/_4$ ounce	22.5 grams
Hydroquinone	$^3/_4$ ounce	22.5 grams
Potassium bromide	$^3/_4$ ounce	22.5 grams
Cold water to make	32 ounces	1.0 liter
Stock Solution *B*		
Cold water	32 ounces	1.0 liter
Sodium hydroxide	$1^3/_4$ ounces	52.5 grams

Dissolve the chemicals in the order given.

For use up to 90°F., mix equal parts of *A* and *B*, and add 10 cc. of formalin (40 per cent) and 10 cc. of phenosafranine solution (1:1000) per liter of mixed developer ($2^1/_2$ drams per 32 ounces).

Ultra-Rapid Developers.—When the film can be processed by machine, and development times of 1 minute or less are desired, the *D-82* developer, with 10 grams of extra sodium hydroxide added per liter (150 grains per 32 ounces), or the *D-8* developer may be used. If the required development time is of the order of $^1/_2$ minute, it may be desirable to add 25 cc. of ammonia to the modified *D-82* developer.

MAXIMUM ENERGY DEVELOPER

(Formula *D-82*)

	Avoirdupois	Metric
Water (about 125°F.) (52°C.)	24 ounces	750.0 cc.
Wood alcohol	$1^1/_2$ ounces	48.0 cc.
Elon	200 grains	14.0 grams
Sodium sulfite (desiccated)	$1^3/_4$ ounces	52.5 grams
Hydroquinone	200 grains	14.0 grams
Sodium hydroxide	125 grains	8.8 grams
Potassium bromide	125 grains	8.8 grams
Water to make	32 ounces	1.0 liter

SINGLE-SOLUTION HYDROQUINONE CAUSTIC DEVELOPER

(Formula *D-8*)

Stock Solution	Avoirdupois	Metric
Water	24 ounces	750.0 cc.
Sodium sulfite (desiccated)	3 ounces	90.0 grams
Hydroquinone	$1^1/_2$ ounces	45.0 grams
Sodium hydroxide	$1^1/_4$ ounces	37.5 grams
Potassium bromide	1 ounce	30.0 grams
Water to make	32 ounces	1.0 liter

Dissolve the chemicals in the order given. For use, take 2 parts of stock solution and 1 part of water.

Developer for Underexposures.—When it is desired to obtain the utmost possible shadow detail from underexposed negatives, the *D-82* developer for underexposure should be used, with a development time of about 8 minutes at 65°F.

Ultra-Rapid Fixation.—When rapid fixation is desired, the hypo concentration of the fixing bath should be increased to 360 grams per liter (12 ounces per 32 ounces). If still more rapid fixation is desired, a non-hardening acid bath with added ammonium chloride may be used. Such a bath should be used, however, only with the two-bath developer or with the *D-9* developer containing formalin, both of which harden the film, and the use of an acid rinse bath between development and fixation is most important. The *F-24* formula is very suitable for this purpose.

NON-HARDENING ACID FIXING BATH

(Formula *F-24*)

	Avoirdupois	Metric
Water (about 125°F.) (52°C.)	16 ounces	500.0 cc.
Sodium thiosulfate (hypo)	8 ounces	240.0 grams
Sodium sulfite (desiccated)	145 grains	10.0 grams
Sodium bisulfite	365 grains	25.0 grams
Water to make	32 ounces	1.0 liter

Dissolve the chemicals in the order given.

To make an ultra-rapid fixing bath, the hypo concentration should be increased to 360 grams per liter (12 ounces per 32 ounces) and 25 grams of ammonium chloride should be added per liter of solution (365 grains per 32 ounces of solution).

SUMMARY

The properties of various developers, including a two-bath hardening developer suitable for the rapid processing of negatives, are described. In the two-bath process, the first solution consists of an elon-hydroquinone developer containing sodium sulfate to prevent excessive swelling, and the second bath contains formalin and sodium sulfite which react to form sodium hydroxide. This second bath, therefore, hardens the emulsion and likewise accelerates the developing action of the developer solution absorbed by the film from the first bath.

The two-bath developer has the following properties:

(*a*) It can be used at temperatures from 65° to 85°F.
(*b*) It develops and hardens the film in 2 minutes.
(*c*) Small errors in timing have very little effect upon the development.
(*d*) The solutions are stable and not very subject to aerial oxidation.

This developer is best followed by the *F-5* fixing bath, but if desired, an ultra-rapid fixing bath, such as the *F-24* with $2^1/_2$ per cent of ammonium chloride added, may be used.

Other developers which are particularly suitable for special circumstances are:

(*1*) For processing normally exposed negatives at room temperatures from 65° to 80°F., use *D-72* full strength, rinse for a few seconds in the *SB-1* acid stop bath, and fix in the *F-23* chrome alum hardening fixing bath.

(*2*) For rapid development at temperatures up to 90°F., use the *D-9* developer with the addition of formalin and phenosafranine, rinse in water or an acid stop bath, and fix in the *F-5* fixing bath.

(*3*) For maximum emulsion speed (maximum shadow detail), regardless of contrast, develop in *D-82* at 65°F. for about 8 minutes.

(*4*) For maximum emulsion speed obtainable in a short time, add 10 grams per liter more sodium hydroxide to the *D-82* and develop at 65°F. for the time available, up to 3 minutes. If the available time is less than 30 seconds, add 2.5 per cent of ammonia to this developer.

(*5*) If maximum highlight density is required regardless of time of development or shadow detail, use *D-8*, *D-9*, or *D-82* plus 1 per cent caustic soda at 65°F. for the time shown in Table II.

(*6*) Provided maximum shadow detail is not required, for maximum gamma in a minimum time, use *D-8* at 65°F.

The time required for drying may be saved by printing from the wet negative, supported in a special holder, or held in a thin liquid cell containing water or fixing bath.

When many prints must be made, the negative should be protected against overheating by providing forced ventilation of the printer lamp house and by the use of a water cell or heat absorbing glass before the lamp.

REFERENCES

[1] CRABTREE, J. I., PARKER, H., AND RUSSELL, H. D.: "Some Properties of Two-Bath Developers for Motion Picture Film," *J. Soc. Mot. Pict. Eng.*, **XXI** (July, 1933), No. 1, p. 21.

[2] "Tropical Development," *Service Dept., Eastman Kodak Co.*, Rochester, N. Y.

[3] GAGE, H. P.: "Heat Absorbing Glass," *Trans. Soc. Mot. Pict. Eng.*, **XII** (1928), No. 36, p. 1063.

[4] COBLENTZ, W. W.: "Radiometric Investigation of Water of Crystallization, Light Filters, and Standard Absorption Bands," *Bulletin U. S. Bur. of Standards*, **7** (May, 1911), p. 655: Scientific Paper No. 168.

[5] GORDON, N. T.: "Water Cooling of Incandescent Lamps," *J. Soc. Mot. Pict. Eng.*, **XIV** (March, 1930), No. 3, p. 332.

FARNHAM, R. E.: "The Water Cooled Lamp" (pamphlet), *Engineering Dept., General Electric Co.*, Cleveland, Ohio.

EQUIPMENT FOR DEVELOPING AND READING SENSITOMETRIC TESTS*

D. R. WHITE**

Summary.—*Two developing machines for laboratory use have been designed and constructed to approximate some of the development characteristics frequently encountered in commercial practice. They are arranged to accommodate only small quantities of film, but rapid film motion is attained by splicing the films into a loop, thus permitting reasonably high linear speeds.*

A photoelectric densitometer was constructed which is in use as a secondary standard of density measurement, the mechanical features of its design affording good reproducibility and rapid operation.

In both routine and research work in sensitometry with motion picture film it is necessary to develop the sensitometric exposures under carefully controlled conditions. Many systems have been proposed to meet this need, some based upon manual and some upon mechanical agitation of the developer or film. In many cases these laboratory systems depart so widely from normal commercial practices that the results attained do not adequately show the results that will be achieved commercially. It is true also that laboratory developing systems depending upon manually agitating the developer are always open to question, as there is usually no proof that the worker has adequately duplicated the agitation conditions from time to time. In view of these facts, two machines have been constructed for use in various phases of sensitometric work.

THE EIGHT-FOOT LOOP MACHINE

For developing small groups of sensitometric tests, a small machine was built, shown in Fig. 1, for film spliced into loops. Agitation is accomplished by driving the film so that its motion through the developer is closely analogous to the film motion in commercial machines. One difference was introduced, however, to reduce greatly the so-called "head-and-tail" effects usually encountered in develop-

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** Dupont Film Mfg. Co., Parlin, N. J.

ing machines in which the film travels uniformly in one direction. Such uniform motion causes products of development to sweep back along the film; and when the exposure is a sensitometric test, with its orderly arrangement of densities, different results are obtained, depending upon whether the film is travelling in such direction as to carry the development products from the lighter to the heavier or from the heavier to the lighter densities. On the other hand, pictures are usually composed of densities randomly arranged; and, so far as development is concerned, the process may presumably be better represented, on the average, by one in which the effect of such orderly density arrangement is minimized. Accordingly, the machine being described was designed to reduce the directional effects by systematically reversing the direction of the film travel. Experiment demonstrated that reversing the direction four times a minute was sufficiently rapid to make it immaterial which way the exposures were oriented upon the film. Tests were made before the machine was constructed, to see whether head-and-tail effects could be eliminated by developer circulation, but it was not found possible in systems of the design tested at any rate of flow that seemed practicable. Hence,

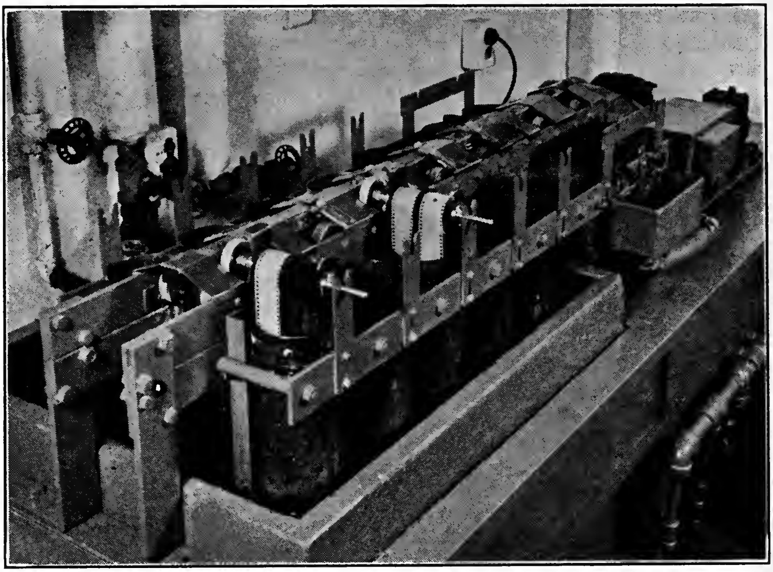

FIG. 1. General view of the 8-ft. loop developing machine.

the reversing drive was adopted, and the developer was allowed to remain stagnant except for such motion as the film imparted to it.

The processing solutions are placed in tubes in the water bath by means of which the temperature is controlled, and the wash tubes are placed immediately outside. The mechanical drive is so arranged as to permit transfer of the racks from tube to tube, and also to allow the film to be driven while in each tube by the motor through the reduction and reversing gears. Fig. 2 shows views of the racks, one as arranged to handle eight feet of film; the other, four feet.

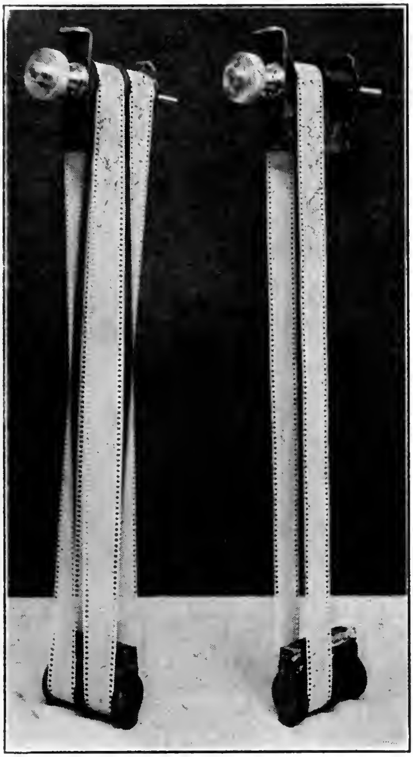

FIG. 2. Racks used in the 8-ft. loop developing machine, one arranged to hold an 8-ft. loop, the other, to hold a 4-ft. loop.

Fig. 3 is a view of the drying cabinet, with one door open so as to show the arrangement of the film within. Blow-offs are provided with which to remove the excess water when the film is first placed in the dryer.

THE FIFTY-FOOT LOOP MACHINE

Practical experience with the small eight-foot loop machine was sufficiently satisfactory to warrant the construction of a larger machine. In this the attempt was made to duplicate more closely the conditions existing in many of the commercial laboratories; accordingly, no reversing drive was introduced. A general view of the

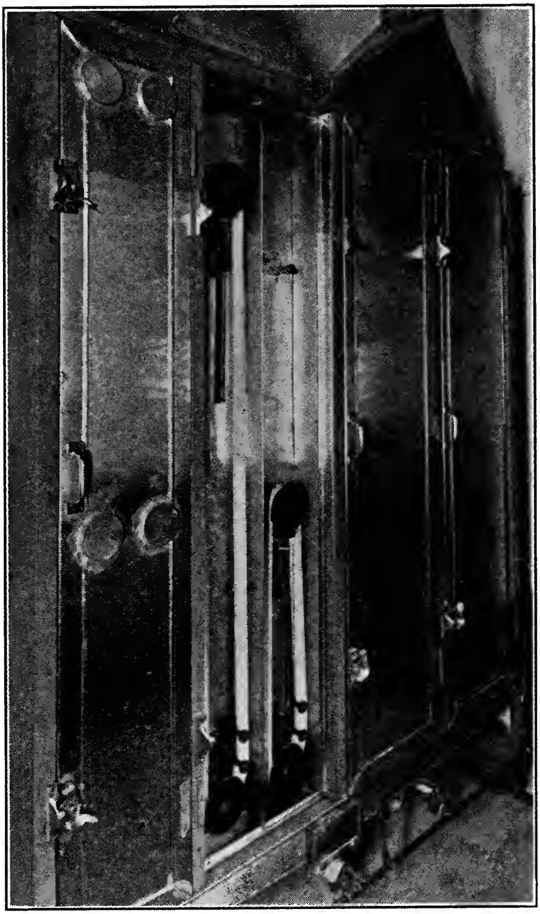

FIG. 3. Drying cabinet for the 4- and 8-ft. loops of film.

machine is shown in Fig. 4. Four developing tanks are provided, for different developers. A portion of the driving mechanism can be seen at the rear of the tanks and in front of a housing that covers the developer circulating machinery and the reserve tanks. The machine, at present, is not arranged for vigorous agitation, but modification of some of the tanks to permit it is readily possible. The rack in the machine drives the film by friction, and hence can accommodate either perforated or unperforated stock. A second rack, shown in Fig. 5, of somewhat greater capacity and different design, handles perforated stock only, and may be used in the machine interchangeably with the other.

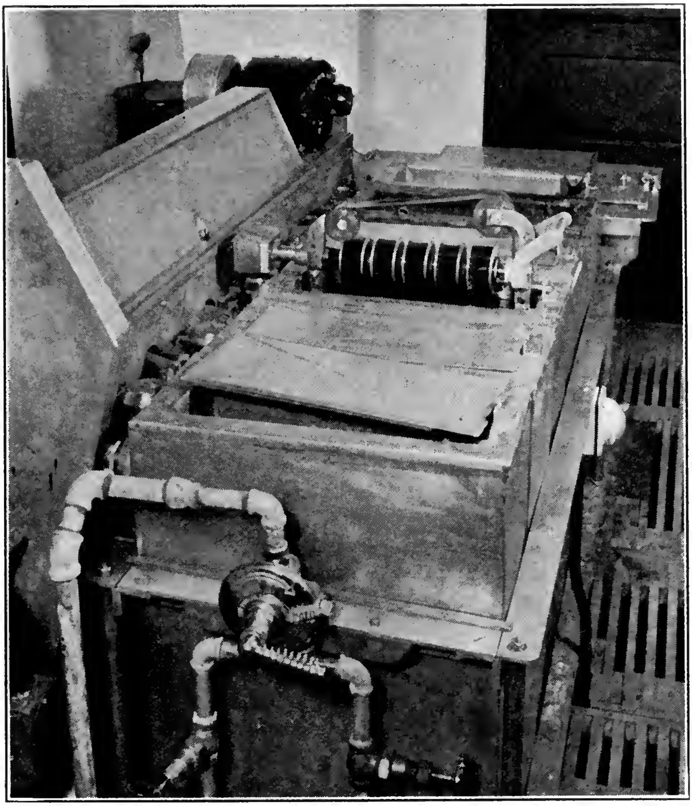

FIG. 4. General view of the 50-ft. loop developing machine, showing the rack used with unperforated film.

Fig. 6 compares results of development of negative film in these machines and with rocking tray. The same developer was used for all three tests. It is at once evident that the rocking-tray development, with its extreme agitation, results in greater density than, but about the same gamma as, the machine developments. The head-and-tail effect is shown by the change in shape of the curves for the fifty-foot loop machine. The strip that passed through the developer low density first has higher densities in the toe and the main part of the curve, but lower densities at the extreme upper end, than the strip oppositely placed upon the film. With the eight-foot loop machine,

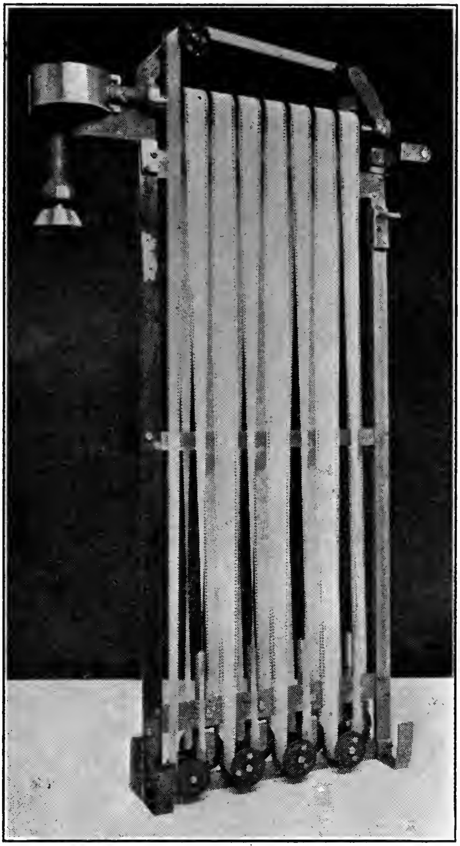

FIG. 5. Rack for perforated film for the 50-ft. loop machine.

the general level of development is comparable with that of the larger machine, but the curve shape is intermediate between the two curves obtained therewith.

With positive film the results shown in Fig. 7 were obtained. Here also the greatest densities were produced by rocking-tray development. Again the head-and-tail effect is evidenced by the different densities produced by orienting the exposures oppositely upon the film, and the development with the eight-foot loop machine is intermediate between these two results. The curves do not extend far enough to show their shapes at the other end of the test strip, but there is every reason to expect a result similar to that attained with negative film.

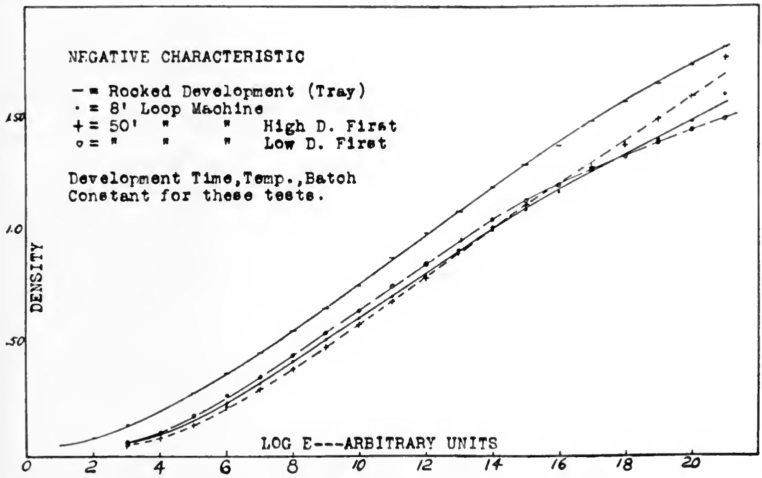

FIG. 6. Sensitometric results with negative film, showing results with rocked-tray development and with each of the two developing machines.

THE PHOTOELECTRIC DENSITOMETER

In order to make the reading of sensitometric tests more rapidly, more mechanical, and less dependent upon the observer, a photoelectric densitometer was designed and built to supplement the visual photometers also in use. Marked improvements have been made in its operation and design to meet efficiently the needs of routine operation by operators possessing little technical training.

The system is shown schematically in Fig. 8. Condensers, *C*, image the ribbon filament of the lamp, *L*, upon the aperture, *A*, through the beam-splitter, *BS*. The light passing through *A* strikes the unknown density, *X*, and the calibrated neutral wedge, *NW*, finally reaching the cell, *PC-1*. The portion split off by the beam-splitter, *BS*, is reflected down to the cell, *PC-2*. The relative response of the two cells is shown by the galvanometer. After adjusting the galvanometer deflection to zero with the high density of the neutral wedge in position, densities may be read by inserting the unknown at *X* and readjusting the calibrated neutral wedge until zero deflection is again obtained. Then the amount by which the density of the wedge has been reduced is equal to the density of the unknown. It is obvious that if the electrical circuit be adjusted so that the two cells respond equally, the ratio of the light striking the unknown density and the light reaching the comparison cell sets an upper limit to the density that can be measured. Theoretically, this ratio of light intensity can be made very high, but practical questions of sensitivity and speed of operation have led to a ratio of approximately 200 to 1, giving a maximum density value of about 2.3 for the instrument.

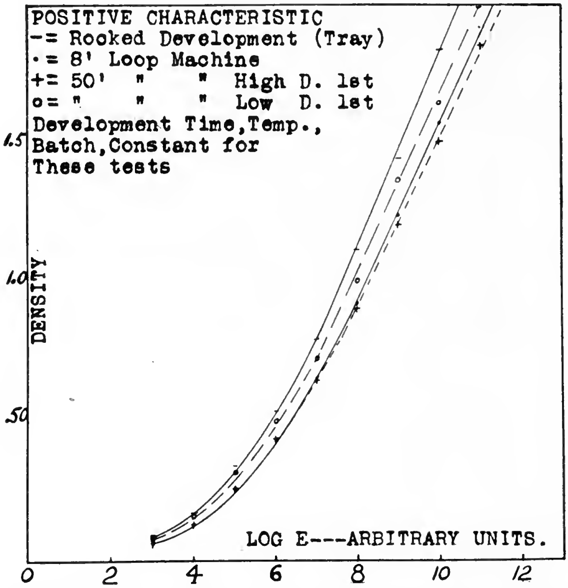

FIG. 7. Sensitometric results with positive film, showing results with rocked-tray development and with each of the two developing machines.

The Weston photronic cells used as the sensitive elements were selected so as to match each other, as greater freedom from trouble due to line-voltage fluctuations could be obtained with matched cells than with cells showing different characteristics.

A general view of the instrument as built is shown in Fig. 9. The neutral wedge moves in covered ways extending from the upper left to the lower right corner of the main plate. Its motion is controlled by the handwheel just below the ways, near the center of the plate, and its position is read by a scale and magnifying glass nearby. Densities to be measured are carried upon a slide in ways extending along the other diagonal of the frame. The lever to the left of the wedge handwheel moves the sensitometric strip from one density to the next. The exciting lamp is behind the main casting, only the chimney of the lamp housing being clearly visible. The lamp, condenser lenses, and beam-splitter are on an optical axis located centrally in the plate and perpendicular thereto. They are on a line with the photronic cell, which is visible and which corresponds to *PC-1* of Fig. 8. The galvanometer scale is visible at the right, with a voltmeter and rheostat for controlling the d-c. field windings of the galvanometer below it. The second photronic cell is in a housing in the lower center of the instrument, and is movable vertically to permit adjusting the ratio of illumination of the two cells. The mechanism governing this movement is shown more clearly in Fig. 10. A dia-

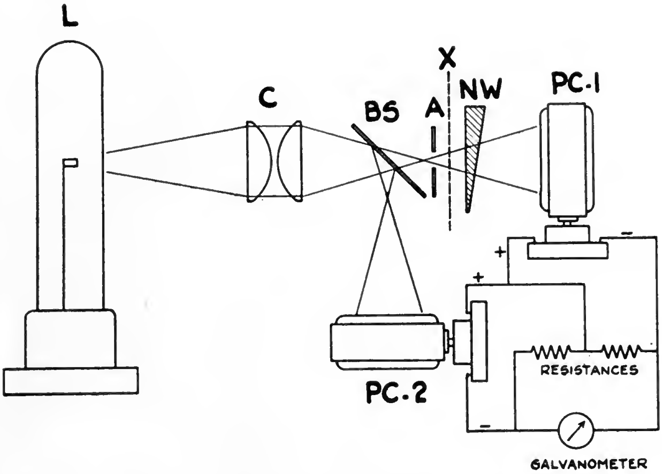

FIG. 8. Schematic diagram of the photoelectric densitometer.

phragm which finally limits the comparison-beam striking the cell can be seen upon the glass cover of the cell.

Some features of the instrument are shown in the next three illustrations, which have nothing to do with the theoretical aspect of the instrument, but which are of great practical importance in operating it.

Fig. 11 is the strip holder which is designed to allow ready insertion or removal of the sensitometric strips. Velvet-covered springs, which may be latched down, hold the strip in place over the row of holes through which the density readings are made. One more hole is provided than there are exposure blocks, to assure an opportunity for measuring the base and fog densities. This is important because the instrument measures the total density rather than the density above fog. With a linear wedge, compensation is readily effected, so as to afford readings with the fog and base subtracted for the exposure densities, by moving the index-mark of the scale.

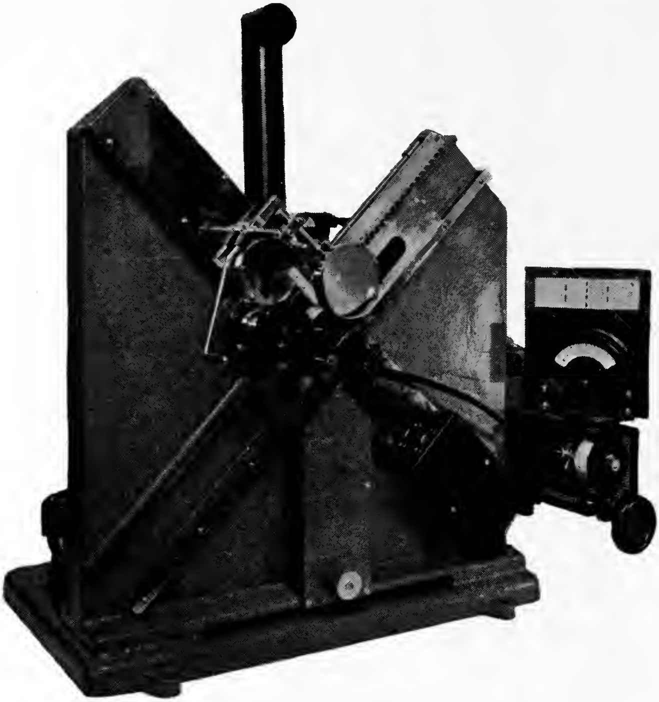

FIG. 9. The assembled photoelectric densitometer.

The strip in its holder is moved from one density to the next by the escapement mechanism shown in Fig. 12. The strip drops by gravity one notch for each operation of the hand-lever, thus permitting rapid changes from one density to the next.

The galvanometer and its mounting are shown in Fig. 13. It is a string galvanometer of the type used in electrocardiographs, in which the string is viewed by projection upon the scale. This type of galvanometer was chosen because a sufficient current-sensitivity could be obtained with a short period. Quick response is directly and fundamentally important to rapid work.

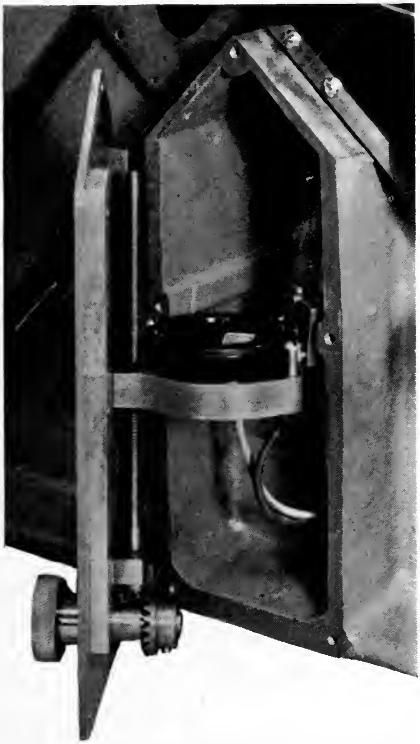

FIG. 10. Detail of the adjustable mount of the comparison photronic cell.

In operation it has been found convenient to provide a switch in the galvanometer circuit to permit checking its condition quickly, both for zero setting and sensitivity. This switch is shown in Fig. 9 at the lower right corner of the main plate. With the lever in the

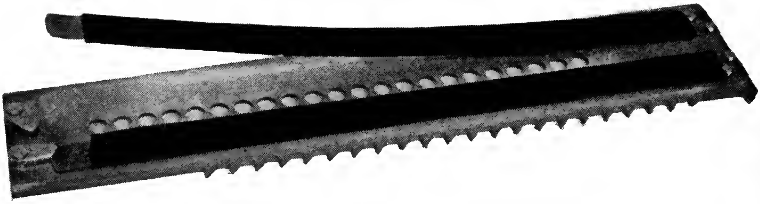

FIG. 11. Strip-holder for the photoelectric densitometer.

central position the string is short-circuited for checking the zero. Moving the lever to one side passes a small test current through the string to check the sensitivity; and moving it to the other side connects it to the photronic cell circuit for operation.

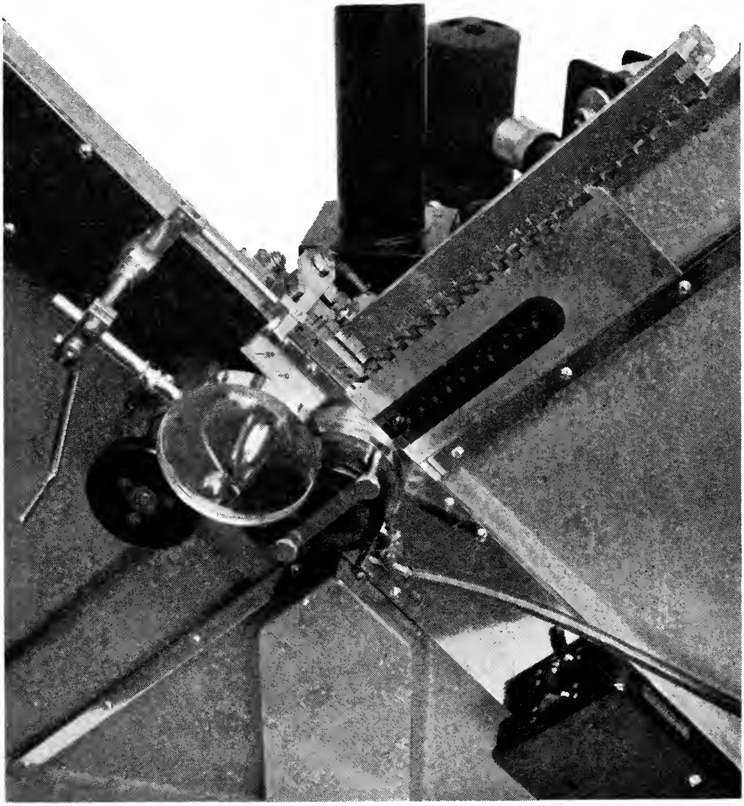

FIG. 12. Escapement mechanism for rapidly moving the strip from density to density.

With this densitometer the conditions of illumination and reading do not correspond with those required to furnish diffuse density values; but by calibrating the wedge in the instrument against polarization photometers, it has been possible to make the instrument a satisfactory secondary standard. The calibration is readily carried out by accurately determining the densities of test-strips, finding the wedge positions for balance, and using these positions as fixed-scale points. The wedges that have been used are the neutral wedges commercially available. The only serious difficulty encountered has been the fading of the wedge at the zero point of the instrument. This has required renewing the wedge from time to time, but it is possible to replace this type of wedge with other materials if the fading is too serious.

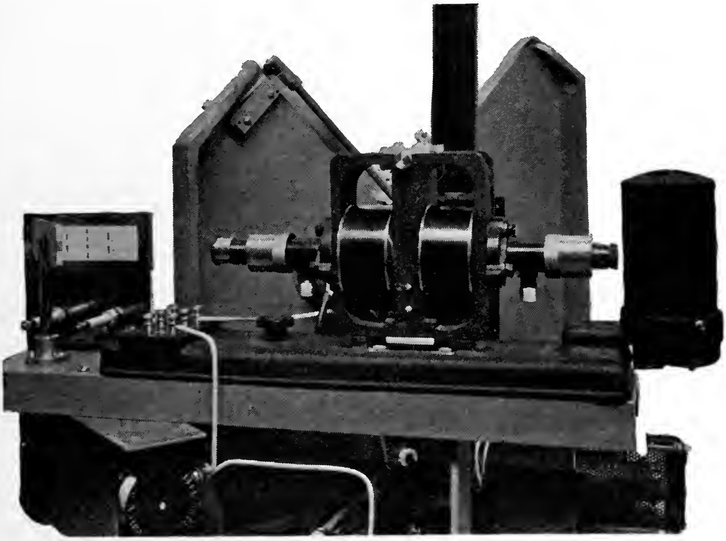

Fig. 13. String galvanometer and its mounting, as part of the photoelectric densitometer

DISCUSSION

MR. CRABTREE: What is the nature of the drive in the developing machine—a friction drive?

MR. WHITE: It is roller drive. One roll is covered with rubber, and the other is knurled so as to receive the drive.

MR. SHEPPARD: I noticed that your value on the plates was considerably higher than for films driven in this apparatus. Recently, at the Paris Inter national Congress, I presented a paper on the subject of automatic developing apparatus for sensitometric strips. Employing plates, which were easy to handle and gave a better idea of the possibilities in that direction, we found that by using a roller and inverting the plate so that the roller moved to and fro at the least possible distance from the plate, we could get considerably higher values of gamma than could be obtained by tray-rocking; and greater uniformity. In tray-rocking a uniformly flashed strip, variations in density from twenty to thirty per cent result, even if the plates are perfectly coated.

With this method, the variation of density across the strip will be two or three per cent. In the case of the drive you describe, where evidently the velocity and the exchange are very small, is there substantial uniformity of density on uniformly flashed material?

Mr. White: That, of course, depends upon the precision that is required. This does not represent such highly precise sensitometry as you describe. I certainly should prefer to base my faith upon plates and the other methods of agitation, where possible and applicable.

Mr. Sheppard: I do not believe it is impossible to do it with film; it is easier to work out the ideal conditions with plates first.

Mr. White: Over the period of time in which we have made reproducibility studies, the results we obtained were as good as or better than we could obtain by any of the other methods.

Mr. Crabtree: What is the time required for reading a strip by this method as compared with the usual optical method?

Mr. White: The operator, with an assistant and with the machine as it stands, can read about 350 H&D strips in an 8-hour day, excluding preparation of report forms and the like. That is a greater output than we obtained with the visual photometers previously used.

REPORT ON PROGRESS IN SETTING UP LABORATORY CONTROLS TO IMPROVE RELEASE PRINT QUALITY*

One of the problems engaging the attention of this Sub-Committee has been that of working out some sensitometric control method which might be put in operation in each laboratory and which would result in a more uniform quality of release print from a given negative, from the standpoint of both picture and sound.

Since it is common industry practice to have release prints made in a laboratory other than that in which the daily work has been developed and printed, there is always the possibility that the release prints may not match the rush prints viewed by the production personnel in the studio.

In attempting to find the solution to this problem it has been assumed that, in general, the quality of the release print should be based upon that shown by the daily print or the master print prepared by the laboratory which processed the original negative.

In addition to the domestic release prints made from negatives prepared in Hollywood, a good many release prints are made in foreign countries, frequently under radically different processing conditions, but which should match the domestic release in picture and sound quality.

PRELIMINARY TESTING OF TENTATIVE STANDARD CONTROL SPECIFICATIONS

Tentative specifications for a standard sensitometric control method have been prepared and are now being given extensive laboratory production tests in several of the studio laboratories in Hollywood. The efforts of the Sub-Committee have been devoted to the establishment of a closer coördination by the West Coast and the East Coast branches of the industry with particular reference to laboratory processing; and before any definite recommendations are made, further tests will be conducted in order to determine the feasibility of the method now being tested for use in the Hollywood, New York, and the foreign laboratories.

The specifications now under consideration contain a series of sensitometric data which it is felt will not only allow a laboratory to duplicate a print from another laboratory from the same negative, but would further allow a comparison of printing machines so that the original light-test cards might be converted without actual re-timing of the negative.

Throughout the period of this work the Sub-Committee has had, and wishes to acknowledge, the very fine coöperation of all the Hollywood and New York laboratories. Methods of control used in each laboratory have been considered in attempting to work out a method which might be easily adopted and applicable

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* Report of Sub-Committee on Improvement in Release Print Quality, of the Standard Sensitometric Control Committee of the Research Council of the Academy of Motion Picture Arts & Sciences, Hollywood, Calif. (Reprinted from the *Technical Bulletin* of the Academy Research Council, July 27, 1935.)

to all the laboratories, and all necessary information requested has been furnished in every instance without hesitation.

During the survey of the methods of control used in each laboratory a comprehensive questionnaire on release printing procedure was prepared and submitted to each of the laboratories both on the East and West Coasts. This questionnaire and compilation will be found at the end of this report.

From a study of the methods of sensitometric control used in the various release print laboratories it was decided that further consideration should be given by the Sub-Committee to the method currently in use in the West Coast Laboratory of Paramount Productions, Inc. In this method of sensitometric control of release print quality, a sensitometric strip on motion picture negative film which has been given normal development is spliced into an appropriate position in the Academy Standard Release Print Leader.

A similar strip, exposed on sound negative film, is similarly spliced into the sound negative leader.

Such strips are placed in the leader of each reel of negative used for printing release.

On each of these strips certain steps are indicated by suitable marking which allows them to be easily identified on the print. These steps are chosen of different densities and cover approximately the full straight-line portion of the negative material.

When a reel has been properly printed, the marked steps on the two strips will produce certain definite densities on the prints. These latter values are then used as a measurable control of release print quality.

SENSITOMETRIC CHECK ON INSPECTION OF PRINTS

Inasmuch as each reel of a release is inspected both for sound and picture, the sensitometric test is a supplementary method of control. Whenever inspection by projection indicates that a reel is defective, the marked steps on the print are measured on a densitometer. These points are sufficiently displaced, so far as negative density is concerned, so that a plot of these points with respect to the negative densities from which they were printed will give the gamma to which the print has been developed.

It is thus possible to determine whether the print has been underprinted or underdeveloped.

This method, with modifications, may be regarded as applicable to obtaining a duplication of quality of the release in several laboratories as well as uniformity of quality of the release in any one organization.

A somewhat similar technic was adopted by the Sub-Committee for making the test, the results of which are now under consideration. A typical picture negative sensitometric strip and comparable sound negative strip were obtained from one of the local studio laboratories. These strips were spliced into individual loops with undeveloped raw stock.

These two loops, serving as test negatives, were then turned over to one of the local release print laboratories (hereafter designated as Laboratory *A*) with a request that:

(1) Prints be made of both in the appropriate printer aperture at each even-numbered light-change,

(2) Control strips be exposed on the end of the print with the positive exposure condition on the Eastman type II*B* sensitometer, and

(3) The whole then be developed in the regular positive processing machine to a control gamma of 2.10.

When Laboratory *A* had completed this test, the negatives were in turn sent to one of the other West Coast release print laboratories (hereafter designated as Laboratory *C*), then to one of the eastern laboratories (Laboratory *D*), back to Laboratory *C*, and finally to another of the Hollywood release print laboratories (Laboratory *B*).

The instructions issued in each case coincided with those given to the superintendent of the original testing Laboratory *A*.

The control gamma obtained on the prints by Laboratory *A* was 2.11, which fulfilled the specifications almost exactly. The first set of prints from Laboratory *C* were developed to a control gamma of 1.74, apparently due to some misunderstanding of the requested conditions. The test from the eastern Laboratory *D* showed a control gamma of 2.26 which was regarded by the Sub-Committee as being beyond the normal tolerance.

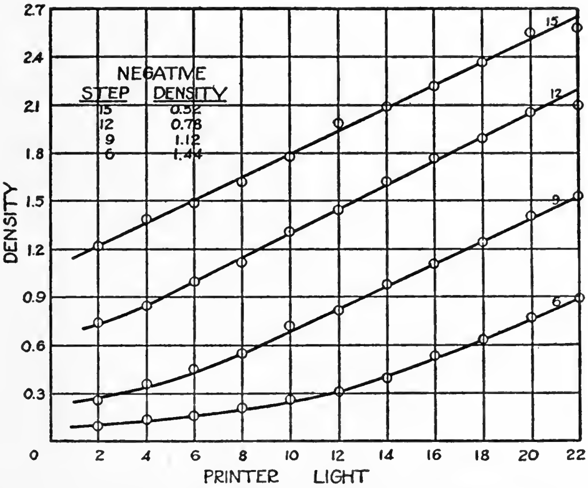

FIG. 1. Picture printing tests: West Coast Laboratory *A*.

The negatives were then returned to Laboratory *C* and another set of prints made, showing a gamma value of 1.96.

Inasmuch as this result was considerably below the specified gamma of 2.10, an investigation was made of the conditions under which the prints were made, which showed that the densitometer in use in that Laboratory gave a gamma value on these same particular control strips of 2.11.

This, of course, introduced a new factor into the specifications—*i. e.*, the fact that all densitometers might not agree in reading and the fact that this variation had not been taken into consideration originally. As a result of this discrepancy, test readings were made on various types of densitometers in the local laboratories, the results of which will be discussed later in this report.

Further investigation elicited the information that the local Laboratory *B* was processing prints to a control gamma of approximately 2.10. The negative test strips were turned over to the superintendent of this laboratory and prints were made in accordance with the original instructions which later gave a control gamma reading of 2.06. This was regarded by the Sub-Committee as being within the tolerance for this particular test.

Having now obtained two sets of prints which had been developed to approximately the same gamma, the print densities were read and the data plotted according to a method previously worked out by the Sub-Committee. This information is shown in Figs. 1 to 4, inclusive.

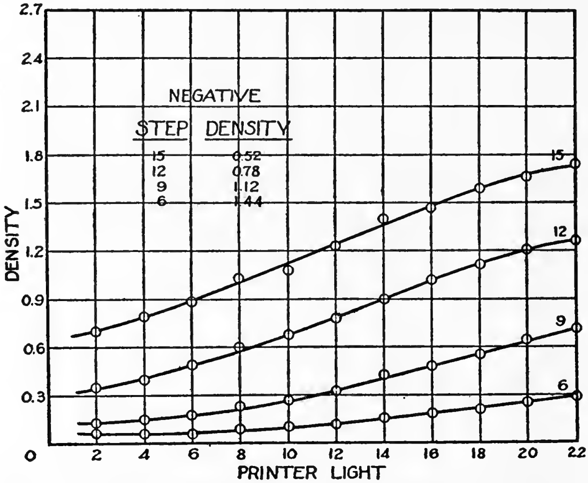

FIG. 2. Picture printing tests: West Coast Laboratory *B*.

In Fig. 1 are plotted the results of the prints of the picture negative strip at Laboratory *A*. Four strips on the negative were chosen, these four having densities of 0.52, 0.78, 1.12, and 1.44. The densities of the prints of each strip were measured on the print at each of the light-changes, and these print densities have been plotted as a function of the light-change. Similar data from the prints of the picture negative strip for the development at Laboratory *B* are shown in Fig. 2 (these two charts being directly comparable to each other).

Figs. 3 and 4 contain similarly plotted data on the prints of the sound negative strip from Laboratories *A* and *B*, respectively.

Superposition of the data on the picture printing test indicates a difference of approximately 10 light-changes between the printers at Laboratory *A* and Laboratory *B*, the former laboratory requiring the lower light-change numbers for a given print density. The fact that the individual curves do not superimpose is due to a slight difference in slope which indicates that the difference of 10 light-changes is not uniform throughout the scale. It is possible by laterally displacing the curves with respect to each other to determine the correlation over the range in common between the two laboratories.

Such a procedure gives equivalent light-changes for picture printing as shown in Table I.

TABLE I

Laboratory *A*	Laboratory *B*
2	11
3	12
4	14
5	15
6	16
7	17
8	18
9	20
10	21
11	22

From Table I it would be possible to use Laboratory *A* printing cards for a print at Laboratory *B* under the condition that the gamma value on the control is 2.10 and for as long as this control gamma was maintained constant, it being necessary merely to use the table to convert to the correct light-change for use of the cards of one laboratory at the other.

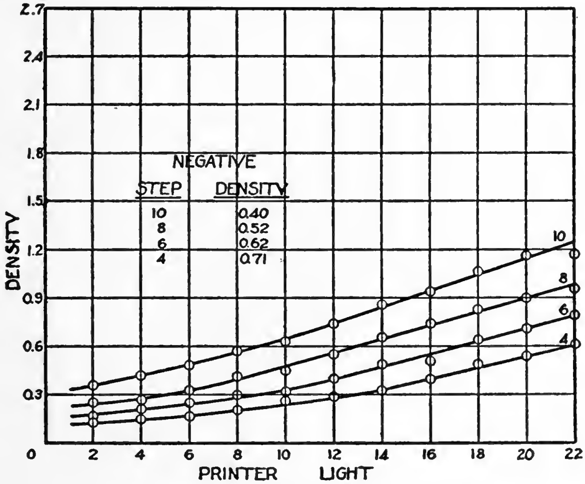

FIG. 3. Sound printing tests: West Coast Laboratory *A*.

Similar examination of the results from the prints of the sound strip gives conversions between the sound aperture light-changes in the two laboratories as shown in Table II.

It appears from these results that it is perfectly feasible for a second laboratory not only practically to duplicate the prints turned out by the original laboratory,

TABLE II

Laboratory *A*	Laboratory *B*
2	2
3	3
4	4
5	5
6½	6
8	7
9	8
12	10
13	11
15	12
16	13
17	14
19	15
20½	16
22	17

but, further, that it would be possible to convert the light-change cards so that it would not be necessary to re-time the negative.

This latter condition is based upon a calibration which it would be necessary to establish between the two laboratories.

One difficulty which appears at the present time is the difference existing between the readings obtained on different densitometers. As was mentioned earlier in this report, one of the local laboratories obtained a gamma reading of 2.11 on a given set of control strips which when read by the Sub-Committee on all other densitometers gave a value of only 1.96.

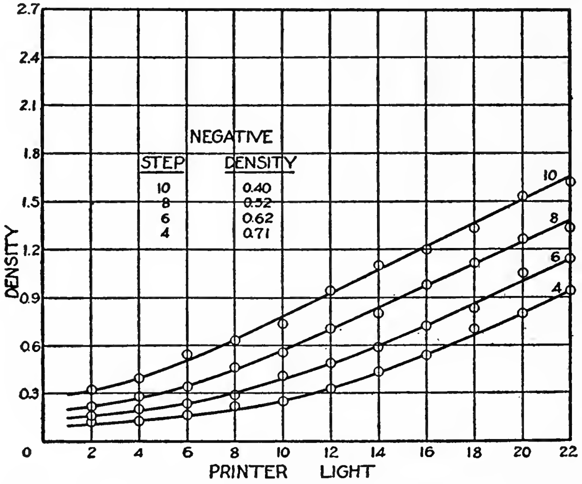

FIG. 4. Sound printing tests: West Coast Laboratory *B*.

All the data given in this report are based upon density readings made on an Eastman densitometer. This particular instrument, which is of the secondary type, has been carefully calibrated against a primary instrument, and is believed to read true diffuse density.

In order to assemble some definite data on the possible variation to be expected between different laboratories, a single sensitometric strip (one of the positive control strips from the tests developed at Laboratory *A*) was read on the instruments listed in Table III.

TABLE III

Densitometer	Location
Eastman	Eastman Kodak Laboratory
Schmidt & Haensch, ERPI	Laboratory *E*
B & L, ERPI	Laboratory *C*
B & L, ERPI	Laboratory *A*
Schmidt & Haensch	Eastman Kodak Laboratory
B & L, ERPI	Studio *Y*
Eastman	Laboratory *B*

The first instrument mentioned in Table III is the one which was used for reading all the tests given in this report. The second is one of the early type Electrical Research Products densitometers using the polarization head manufactured by the Schmidt & Haensch organization. The Schmidt & Haensch instrument at the Eastman Kodak Laboratory is the same head as that on the densitometer at Laboratory *E*, but is mounted quite differently.

The densitometer in this plant has been calibrated against the same primary standard as the Eastman densitometers, and therefore agrees with them.

The Schmidt & Haensch as mounted and used at the Eastman Laboratory is calibrated strictly against the Cot^2 of the angle of rotation of the Nicol prism, and it is known that this instrument reads high (in density) above a value of 1.40 because of scattered light.

In Table IV are given the comparative density readings from the several densitometers enumerated in Table III, together with the gamma values obtained from plotting these readings.

It will be seen that the results fall into two groups, both the Eastman densitometers, the B & L instruments at Laboratory *A* and Studio *Y*, and the Schmidt & Haensch at Laboratory *E* agreeing with each other, while the Bausch & Lomb at Laboratory *C* and the Schmidt & Haensch at the Eastman Kodak Laboratory read increasingly higher density at the upper end of the scale, with a resulting higher gamma value.

This survey, which covers only a few of the Hollywood laboratories, shows that some differences exist between densitometers, and it can only be supposed that similar differences exist between instruments in use in other laboratories in the East and in the foreign field.

Until this condition is rectified, any efforts to standardize release printing conditions are subject to differences in one of the essential yardsticks used for the measurement of print characteristics and consequently will not result in appreciable progress.

Recognizing this fact, the Sub-Committee plans to establish a set of standard densities to which densitometers in use in the individual laboratories may be compared and correlated. An account of this phase of the Sub-Committee activity is contained in a later portion of this report.

At the present time the sensitometers used for the exposure of sensitometric control strips are quite uniform, the Eastman type II*B* sensitometer, which was designed specifically for motion picture laboratory use, being widely used in the industry not only in Hollywood and New York, but abroad as well.

TABLE IV

Comparative Density Readings and Plotted Gamma Values

Step	Eastman; Eastman Kodak Co.	Schmidt & Haensch, ERPI; Laboratory *E*	B & L ERPI; Laboratory *A*	B & L ERPI; Studio Y	Eastman; Laboratory *B*	B & L ERPI	Schmidt & Haensch, Eastman Kodak Co.
10	2.47	..	2.48	2.42	2.49	2.62	..
11	2.18	2.15	2.20	2.10	2.17	2.25	2.25
12	1.82	1.82	1.86	1.78	1.85	1.87	1.91
13	1.50	1.51	1.53	1.42	1.52	1.52	1.55
14	1.16	1.17	1.20	1.12	1.18	1.18	1.21
15	0.85	0.83	0.89	0.84	0.88	0.85	0.83
16	0.57	0.55	0.58	0.54	0.59	0.56	0.55
17	0.34	0.33	0.37	0.33	0.35	0.34	0.33
18	0.19	0.17	0.21	0.18	0.20	0.20	0.17
19	0.10	0.09	0.14	0.10	0.10	..	0.08
γ	2.17	2.22	2.18	2.14	2.18	2.32	2.40

STANDARD DENSITIES

As brought out previously in this report, results of tests conducted by the Sub-Committee indicated a wide variance in the calibration of densitometers used in the various release printing laboratories, and there seemed to be a definite need for some standard to which densitometer readings in each of the laboratories might be correlated and compared.

After a considerable investigation of the various materials which might retain their properties over a sufficiently long period of time to be suitable for use in a set of standard densities, a sensitometric strip of platinum sputtered on glass appeared to be the most feasible from a mechanical as well as a photographic standpoint.

An experimental set of "possible-standard" densities is now being made in the astronomical laboratories at the California Institute of Technology and the Mount Wilson Observatory at Pasadena, Calif.

If present indications prove correct, it will be possible to establish a set of long-life standard densities to which all densitometers may be correlated, and which will enable any laboratory to compare directly readings made on one densitometer with readings made on any other densitometer in any other laboratory.

This experimental set of densities will be completed and tested in the near future, and it is hoped that definite recommendations for the establishment of the standard densities may be ready for submission to the producing companies and commercial laboratories with whatever recommendations for the establishment of a standard method of sensitometric control may be made upon the completion of the tests described previously in this report.

Standard Sensitometric Control Group of the Research Council Sub-Committee on Improvement in Release Print Quality

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COMPILATION OF ANSWERS TO QUESTIONNAIRE ON RELEASE PRINT LABORATORY PRACTICE*

As a first step, the Standard Sensitometric Control Group prepared and circulated a general questionnaire to all laboratories making release prints, designed to obtain a comparison of the controls utilized in each laboratory. A very good response was obtained, twelve release print laboratories having returned fully completed questionnaires.

A compilation of these questionnaires is presented below. For the purpose of this report, no designation by name of the particular laboratory is recorded, the laboratories merely being numbered from *1* to *12*. The compilation is so arranged that all the answers received to any one question are grouped under that question. A picture of the complete practice at any one laboratory may obviously be obtained by inspecting the answers to each question listed under any one laboratory number.

For purposes of the investigation, the questionnaire was divided into five general classifications, *i. e.*, I—Sensitometers, II—Densitometers, III—Sensitometric Procedure on Release Prints, IV—Release Inspection, and V—Printers.

I. SENSITOMETERS

(*1*) *What type of sensitometer do you use?*

Laboratory	Answer
1	Time-scale
2	Time-scale Eastman type II*B*
3	Time-scale Eastman type II*B*
4	Time-scale Eastman type II*B*
5	Time-scale Eastman type II*B*
6	Time-scale
7	Intensity-scale
8	Time-scale
9	Time-scale
10	Time-scale
11	Time-scale
12	Time-scale (Eastman Kodak Co. supplies sensitometric strips)

(*2*) *What is the color temperature of the light-source?*

Laboratory	Answer
1	3000°K.
2	5400°K. (negative); 3000°K. (positive)
3	5400°K. (negative); 3000°K. (positive)

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4	3000°K.
5	3000°K.
6	3000°K.
7	2650°K.
8	Approx. 3000°K.
9	5400°K. (negative); 3000°K. (positive)
10	5400°K. (negative); 3000°K. (positive)
11	....
12	....

(*3*) *What is the illumination at the exposure plane in meter-candles?*

Laboratory	Answer
1	27.0
2	0.75 (negative); 27.0 (positive)
3	....
4	27.0
5	27.0
6	27.0
7	340
8	27.0 (positive)
9	0.75 (negative); 27.0 (positive)
10	0.75 (negative); 27.0 (positive)
11	112.3
12	0.75 (negative); 27.0 (positive)

(*4a*) *If Time-scale, what is the step ratio?*

Laboratory	Answer
1	$\sqrt{2}$
2	$\sqrt{2}$
3	...
4	$\sqrt{2}$
5	$\sqrt{2}$
6	$\sqrt{2}$
7	(Intensity-scale, see Question 4*b*)
8	$\sqrt{2}$
9	$\sqrt{2}$
10	$\sqrt{2}$
11	...
12	$\sqrt{2}$

(*4b*) *If Intensity-scale, what is the color coefficient of the tablet?*

Laboratory	Answer
7	1

(*5a*) *If Time-scale, what is the time of maximum exposure?*

Laboratory	Answer
1	4.99 seconds
2	4.99 seconds
3	4.99 seconds

4	4.99 seconds
5	4.99 seconds
6	4.99 seconds
7	(Intensity-scale, see Question 5*b*)
8	4.99 seconds
9	4.99 seconds
10	. .
11	2.05 seconds
12	4.99 seconds

(*5b*) *If Intensity-scale, what is the time of exposure?*

Laboratory	Answer
7	0.25 second

(*6*) *How often is your sensitometer calibrated?*

Laboratory	Answer
1	Semi-monthly
2	Every two weeks
3	Every 200 hours of use
4	Every 10 days
5	Every 10 days
6	Semi-monthly
7	Monthly
8	Weekly
9	Every six weeks
10	Semi-monthly
11	Every week
12	Semi-monthly

(*7*) *What standard is used?*

Laboratory	Answer
1	Checked by Eastman
2	Eastman standard
3	Eastman standard
4	Calibrated against Eastman standard
5	Eastman standard
6	Eastman standard
7	Calibrated lamp
8	Eastman standard
9	Eastman standard
10	Eastman standard
11	Eastman standard
12	Eastman standard

II. DENSITOMETERS

(*8*) *What type of densitometer do you use?*

Laboratory	Answer
1	Eastman visual diffuse
2	Bausch & Lomb K.S. 6466 visual diffuse

3	Eastman visual diffuse
4	Bausch & Lomb visual diffuse
5	ERPI polarization visual diffuse
6	Schmidt & Haensch, Eastman visual diffuse
7	Western Electric and Eastman visual diffuse (also photoelectric)
8	Eastman visual diffuse; Bausch & Lomb (visual specular and photoelectric for experimenting)
9	Eastman visual diffuse
10	Eastman visual specular
11	Bausch & Lomb
12	Eastman visual diffuse

(9) *What type of diffusion is used?*

Laboratory	Answer
1	Flashed opal glass
2	Flashed opal glass
3	Flashed opal glass
4	Opal glass
5	Pot opal glass
6	Opal glass
7	Opal glass
8	Opal glass
9	Opal glass
10	Opal glass
11	....
12	Opal glass

(10) *How often is your densitometer checked?*

Laboratory	Answer
1	Every two weeks
2	Checked only at factory before delivery
3	Daily
4	Daily
5	Weekly
6	Daily by standard calibrated wedge
7	Monthly
8	Monthly against Eastman standard
9	Every six weeks
10	Weekly
11	Weekly
12	Checked by Eastman monthly, our own standards weekly

(11) *What method is used?*

Laboratory	Answer
1	Calibration against standard by Eastman Kodak Co.
2	....
3	Checked to a strip of known density
4	Checked before using, at zero reading; our own density standards are also used

5	Checked against density standards which are checked with Eastman Kodak Co. standards
6	By standard calibrated wedge
7	Calibrated photographic density
8	Standard densities
9	Comparison with polarization type instruments
10	Checked by Eastman standard density strip
11	Neutral density strips and standard tablets are read
12	....

III. SENSITOMETRIC PROCEDURE ON RELEASE PRINTS

(*12*) *Do you attach a strip to each roll? If not, at what intervals?*

Laboratory	Answer
1	....
2	Hourly
3	Independent strips run through every two hours
4	At end of each copy
5	Strip is added every half-hour during processing
6	Hourly
7	Half-hour intervals
8	Yes
9	Separate strip every half-hour
10	Half-hourly
11	Each roll
12	....

(*13*) *Are sensitometric control strips made from same emulsion as that on which the release is being printed?*

Laboratory	Answer
1	...
2	Yes
3	Yes
4	Yes
5	Yes
6	Yes
7	Yes
8	Yes
9	Yes
10	Yes
11	Yes
12	...

(*14*) *Do you use a printed-through sensitometric strip, if such a strip is furnished on the negative?*

Laboratory	Answer
1	...
2	No
3	No

4	No
5	Yes
6	No
7	If desired by customer
8	No
9	No
10	No
11	Yes
12	. . .

(15) *If printed-through strips are used, do you depend entirely upon them for standardization, or do you use separate sensitometric checks as well?*

Laboratory	Answer
1	. . . .
2	. . . .
3	. . . .
4	Occasional checks are made with printed-through strips
5	Printed-through strips are used as secondary check mainly for density
6	Used for balancing printing machine
7	. . . .
8	Separate sensitometric strips
9	Separate sensitometric checks
10	Separate sensitometric checks
11	Both
12	. . . .

(16) *What is your desired gamma?*

Laboratory	Answer
1	. . . .
2	Positive, 2.30
3	2.20
4	2.40
5	2.15
6	. . . .
7	2.10
8	2.00
9	2.15
10	2.10
11	2.00
12	2.00

(17) *How closely can you hold to your desired gamma?*

Laboratory	Answer
1	. . . .
2	0.05
3	5 per cent
4	0.05
5	2.10 to 2.25

6	2 per cent
7	Stock variation
8	±5 per cent
9	0.05
10	2.05 to 2.15
11	±0.1
12	2.00 to 2.20

(*18*) *How far would the gamma have to vary from your desired point before the print would be rejected?*

Laboratory	Answer
1	....
2	0.08.
3	No prints rejected on readings alone, but run for sound quality.
4	0.10.
5	5 per cent tolerable variation.
6	5 per cent.
7	Depends on subject.
8	If below 1.90, or above 2.10.
9	Approximately 5 per cent plus or minus.
10	0.05 above to 0.05 below standard.
11	Depends upon result.
12	1.80 to 2.20.
12	1.80 to 2.20.

(*19*) *What density measurements are made on release prints?*

Laboratory	Answer
1	....
2	Biased transmission, 13 to 15 per cent.
3	Every print measured for density (any print falling outside a given range is then played for sound quality).
4	....
5	Bias and head strip densities made on first release copies. No other density measurements on succeeding prints unless quality or volume warrants.
6	....
7	Unbiased, unmodulated control strip of every roll.
8	Sound-track density, picture density, and gamma.
9	Density readings of unmodulated control strips variable-density tracks when available.
10	Each reel is measured by checking the unbiased cut-in check strip inserted at the beginning of each reel. To date our sound product is a complete re-recording process; therefore it is only necessary to check the unbiased portion at the beginning of each reel, the correct density of biased portion throughout the reel being determined by the amount of noise reduction used.
11	Unmodulated and unbiased track density as well as printed-through.
12	Approximately 28 per cent.

(*20*) *What qualifications must your sensitometric control men fulfill?*

Laboratory	Answer
1	Head sensitometric man, twenty years in motion picture laboratory work; high-school education. Assistant, 2 years' experience; $2^1/_2$ years university.
2	Day man, 5 years' experience various studios; education, one year western university. Night man, radio broadcasting experience, plus $4^1/_2$ years in the laboratory.
3	Experienced laboratory men trained for this work, with high-school and college education.
4	Research and laboratory experience, high-school and college experience or equivalent.
5	Foreman, technical training and practical experience, plus college education. Assistant, practical experience, plus high-school education.
6	Efficient laboratory men trained in this work in this organization.
7	Degree from a recognized college and no experience in film business. Men are trained here to our own methods.
8	Average about eight years' laboratory experience; one college graduate and three not graduated.
9	Laboratory experience and sensitometric knowledge.
10	....
11	Prefer college men with engineering background.
12	Experienced laboratory men with acquired sensitometric knowledge.

IV. RELEASE INSPECTION

(*21*) *Do you inspect each and every print for both sound and picture?*

Laboratory	Answer
1	....
2	Every print inspected for picture, sound inspected by measurement, twice daily, one reel of each printing machine inspected for sound by projection.
3	All prints inspected by projection for density, picture quality, and cleanness. Sound density is read on every print. Synchronism is checked by corresponding marks printed from picture and sound negatives. Mislight on sound is checked by printer light going out at end of reel.
4	Every print by theater projection at 90 feet per minute.
5	Each print visually on small screen, each inspector equipped with head-phones for sound inspection at 90 feet per minute.
6	Each print given general visual inspection at 100 feet per minute.
7	Each print inspected by projection in individual booths with loud speakers, and track projected on screen at 90 feet per minute.
8	Each print by projection in sound room at 90 feet per minute.
9	Each print inspected for picture and sound visually at 90 feet per minute and a percentage of the product is inspected audibly as well.

10	Master composite checked in theater (sound and action projection), following copies inspected on cold-light projectors, visual projection of sound-track on screen, at 90 feet per minute.
11	Each print inspected at normal speed by projection.
12	Each print inspected at normal speed by projection in regular projection room.

(*22*) *From the laboratory standpoint, how much time would you consider ideal to turn out the first satisfactory print from a new release negative?*

Laboratory	Answer
1	24 hours.
2	2 to 3 days for final correction in printing lights, requiring 2 to 3 complete prints.
3	4 days (including preparation of and numbering negatives, time-cards, timing negatives, and correction of sample print).
4	24 hours.
5	4 copies (time required to send through 4 copies and check each one for improvement in density balance would be 2 days).
6	2 days.
7	3 days.
8	4 days.
9	Average of 3 hours per reel.
10	48 hours.
11	8–16 hours.
12	1 day (for a 2-reel picture).

V. PRINTERS

(*23*) *What type of printer do you use for sound? For picture?*

Laboratory	Answer
1	Bell & Howell (sound and picture).
2	Bell & Howell (sound). Adapter (picture).
3	Special design (sound). Step printer (picture).
4	Bell & Howell continuous (sound and picture).
5	Bell & Howell model *D* (sound and picture).
6	Bell & Howell model *D* (sound and picture).
7	Modified Bell & Howell (sound and picture).
8	Bell & Howell (sound and picture).
9	Continuous (sound). Step printer (picture).
10	Bell & Howell (sound and picture).
11	Bell & Howell (sound and picture).
12	Bell & Howell (sound and picture).

(*24*) *Do you print sound and picture simultaneously?*

Laboratory	Answer
1	No
2	Yes
3	Yes
4	No
5	No

6	Yes
7	Yes
8	No
9	Yes
10	No
11	No
12	No

(*25*) *What is your printer film speed?*

Laboratory	Answer
1	80 feet per minute.
2	75
3	37.5
4	48
5	62
6	60
7	90
8	80
9	75
10	80
11	60
12	58

(*26*) *Type of light-source?*

Laboratory	Answer
1	....
2	Incandescent ground glass globe.
3	60-w clear.
4	75-w G. E. Mazda (long filament).
5	Special Mazda, 100-w, 115-v.
6	....
7	*B* type cage filament, 115-v.
8	60-w Mazda.
9	100-w, 110-v Mazda frosted.
10	75-w inside frosted, pear-shaped incandescent lamp, 115-v d-c.
11	Incandescent lamp.
12	Old style Mazda lamp, 75-w.

(*27*) *Do you check for printer contact and slippage? If so, how?*

Laboratory	Answer
1	Checked by sound department.
2	Test-strips twice a day, also one complete reel from each machine twice a day.
3	Contact checked by means of 6000-cycle negative attached to machine test, which is examined for sharpness; slippage check by evenness of exposure on piece of unmodulated negative attached to machine test.
4	Check gate for contact; check belt for slippage.
5	Routine check once each month for contact and slippage. However,

	if trouble is encountered, check is made more frequently—test is usually made by printing from a negative with fine criss-cross lines.
6	Visual observation of test print from standard negatives and electrical measurement of high-frequency losses.
7	Yes (for contact).
8	Contact and slippage daily by registration print.
9	Check frequency test-strips microscopically for slippage and percentage of daily production in same manner.
10	By printing a sound negative with recordings at 100, 1000, 7000 cycles. The print is then run on a re-recording machine checked on standard VI meter for decibel fluctuation and tone quality projection. Variation in negative compensated by running negative also.
11	Yes, by actual film test.
12	Regulation check as per contact test made with two pieces of film. For slippage test we use a speedometer on each machine.

(*28*) *Do you check the printing machines within your plant with each other, step for step? How do you do it?*

(For example: If a given scene printed on light *15* on one printing machine, how closely to this do you try to keep the other printing machines within the plant?)

Laboratory	Answer
1	Checked visually and by reading exposure on densitometer.
2	We strive to keep printing machines within one-half point either way.
3	100 per cent.
4	We try to keep them all alike.
5	Both sound and picture apertures on each machine are checked and balanced with an accepted standard. Each light matches exactly on all machines.
6	One-half point.
7	All machines are kept identically a known distance apart at one step in center of scale, and such scale variations as there are, are known to us and allowed for in timing. Checking is done by printing a loop on machines in question and on all machines frequently.
8	Each individual step on each printer as well as testing machines is checked against a standard twice daily. Also the light value of the printer on each step is checked with a photronic cell in a bridge circuit with an L & N galvanometer.
9	Printing lights are matched on all machines so that the same result is obtained on a given scene from corresponding lights.
10	A scene printing on light *15* on one printer would print on the same light on all printers. A standard negative is used for sound and action density checks, and any difference in the printers compensated for by a slight voltage adjustment within a given range

	whereby printer gamma is not affected. The above constitutes a visual and sensitometric check.
11	Yes, by checking each machine with the same negative of picture and unbiased unmodulated track.
12	We have only two printers and they are identically alike.

(29) *How frequently are printing machines checked* (*a*) *for balance;* (*b*) *for contact and slippage?*

Laboratory	Answer
1	Daily.
2	Twice daily.
3	Daily.
4	Twice daily (*balance*). Daily (*contact and slippage*).
5	Three times daily (*balance*). Monthly (*contact and slippage*).
6	Every 6 hours.
7	Twice a week.
8	Twice daily.
9	Bi-weekly (*balance*). Daily (*contact and slippage*).
10	Daily for density; weekly for printer gamma (*balance*). Weekly (*contact and slippage*).
11	Daily.
12	Daily.

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(*Correct to March 20, 1936; additional appointments may be made at any time during the year as necessity or expediency may require*)

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HEADQUARTERS

The Headquarters of the Convention will be the Edgewater Beach Hotel, where excellent accommodations and Convention facilities are assured. A special suite will be provided for the ladies. Rates for SMPE delegates, European plan, will be as follows:

One person, room and bath	$3.00
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	5.00
Parlor suite and bath, for two	10.00 and 12.00

Room reservation cards were mailed to the membership of the Society recently, and every one who plans to attend the Convention should return his card to the Hotel promptly in order to be assured of satisfactory accommodations.

A special rate of fifty cents a day has been arranged for SMPE delegates who motor to the Convention, in the Edgewater Beach Hotel fireproof garage. Private *de luxe* motor coaches operated by the Hotel will be available for service between the Hotel and the Chicago Loop area.

TECHNICAL SESSIONS

An attractive program of technical papers and presentations is being arranged by the Papers Committee. All sessions and film programs will be held in the *East Lounge* of the Hotel.

APPARATUS EXHIBIT

An exhibit of newly developed motion picture apparatus will be held in the *West Lounge* of the Hotel, to which all manufacturers of equipment are invited to contribute. The apparatus to be exhibited must either be new or embody new features of interest from a technical point of view. No charge will be made for space. Information concerning the exhibit and reservations for space should be made by writing to the Chairman of the Exhibits Committee, Mr. O. F. Neu, addressed to the General Office of the Society.

SEMI-ANNUAL BANQUET

The Semi-Annual Banquet and Dance of the Society will be held in the Ballroom of the Edgewater Beach Hotel on Wednesday, April 29th, at 7:30 P.M. Addresses will be delivered by eminent members of the motion picture industry, followed by dancing and entertainment.

INSPECTION TRIPS

Arrangements may be made, upon request at the registration desk, to visit and inspect, in small groups, various laboratories, studios, and equipment manufactories in the Chicago area. Firms that have extended invitations to such groups are:

- Burton Holmes Films, Inc.
- Bell & Howell Company
- Chicago Film Laboratories, Inc.
- Da-Lite Screen Company, Inc.
- Enterprise Optical Manufacturing Company
- Herman H. DeVry, Inc.
- Holmes Projector Company
- J. E. McAuley Manufacturing Company
- Jam Handy Pictures Corp.
- Jenkins & Adair, Inc.
- National Screen Service, Inc.
- Western Electric Company
- Wilding Picture Productions, Inc.
- Society of Visual Education

POINTS OF INTEREST

To list all the points of interest in and about Chicago would require too much space, but among them may be mentioned the following:

- Field Museum of Natural History
- Adler Planetarium and Astronomical Museum
- Art Institute
- Museum of Science and Industry
- Chicago Historical Society
- Academy of Science
- Lincoln Park
- National Underwriters' Laboratories
- Oriental Institute
- John G. Shedd Aquarium
- Lincoln Park Aquarium
- Lincoln Park Zoological Gardens
- Chicago Zoological Gardens
- Grant Park
- University of Chicago
- Loyola University
- Northwestern University

Complete information concerning and directions for visiting these places will be available at the Hotel.

RECREATION

A miniature nine-hole golf course, putting greens, and regulation tennis courts, maintained by the Hotel, will be available to SMPE delegates registered at the Hotel. Details will be available at the registration desk. Special diversions will be provided for the ladies, and passes to local theaters will be available to all delegates registering.

TENTATIVE PROGRAM

MONDAY, APRIL 27th

9:00 a. m.	**Registration.**
10:00 a. m. to 12:00 p. m.	*East Lounge;* **Business and Technical Session.** Address of Welcome; H. G. Tasker, *President.* Report of the Convention Committee; W. C. Kunzmann, *Convention Vice-President.* (5 min.) Report of the Membership Committee; E. R. Geib. *Chairman.* (5 min.)

Report of the Progress Committee; J. G. Frayne, *Chairman.* (20 min.)

"Organization and Work of the Film Library;" John E. Abbott, *Director,* The Museum of Modern Art Film Library, New York, N. Y. (*Demonstration.*) (25 min.)

"The Application of Sound Motion Pictures to Criminal Identification;" Col. H. N. Schwarzkopf, *Superintendent,* New Jersey State Police, Trenton, N. J. (*Demonstration.*) (25 min.)

12:30 p. m. *South Room;* **Informal Get-Together Luncheon.**

For members and guests.

2:00 p. m. to 5:00 p. m. *East Lounge;* **Sound Session.**

Report of the Sound Committee; P. H. Evans, *Chairman.*

"Photoelectric Cells and Their Method of Operation;" M. F. Jameson and T. E. Shea, Bell Telephone Laboratories, Inc., New York, N. Y. (*Demonstration.*) (1 hour)

"Harmonic Distortion in Variable-Density Recording;" B. F. Miller, Warner Bros. Pictures Corp., Hollywood, Calif. (15 min.)

"Critically Damped Filters;" J. Livadary, Columbia Pictures Corp., Hollywood, Calif. (15 min.)

"Increased Resolution in Sound Recording and Printing through the Use of Ultraviolet Light;" G. L. Dimmick, RCA Manufacturing Co., Inc., Camden, N. J. (*Demonstration.*) (25 min.)

8:00 p. m. *East Lounge;* **Film Program.**

Exhibition of recent outstanding feature and industrial motion pictures.

TUESDAY, APRIL 28th

10:00 a. m. to 12:00 p. m. *East Lounge;* **General Technical Session.**

"The Acoustic Design of Music Scoring Stages;" C. M. Mugler, Acoustical Engineering Co., Los Angeles, Calif. (*Demonstration.*) (20 min.)

"Acoustic Considerations in the Construction and Use of Sound Stages;" P. D. Loye, Electrical Research Products, Inc., Los Angeles, Calif. (*Demonstration.*) (20 min.)

"A High-Quality Reproducing System for Small Theaters;" H. P. Pfannenstiehl, E. O. Scriven, and J. F. Hoge, Bell Telephone Laboratories, Inc., New York, N. Y. (25 min.)

"The RCA Recording System;" B. Kreuzer, RCA Manufacturing Co., Inc., Camden, N. J. (20 min.)

Report of the Standards Committee; E. K. Carver, *Chairman.* (10 min.)

2:00 p. m. to 5:00 p. m. *East Lounge;* **Lighting Symposium.**

Report of the Projection Screen Brightness Committee; C. Tuttle, *Chairman.* (15 min.)

Report of the Projection Practice Committee; H. Rubin, *Chairman.* (15 min.)

"The Motion Picture Screen as a Lighting Problem;" M. Luckiesh and F. K. Moss, General Electric Co., Cleveland, Ohio. (25 min.)

"Source Construction and Color of Light from Some Incandescent Lamps;" R. E. Farnham and R. E. Worstell, General Electric Co., Cleveland, Ohio. (20 min.)

"Present Trends in the Application of the Carbon Arc to the Motion Picture Industry;" W. C. Kalb, National Carbon Co., Inc., Cleveland, Ohio. (20 min.)

"Theory and Use of Photoelectric Exposure Meters;" A. T. Williams, Weston Electrical Instrument Corp., Newark, N. J. (20 min.)

"A 13.6-Mm. Super-High-Intensity Carbon;" D. B. Joy, National Carbon Co., Inc., Fostoria, Ohio.

WEDNESDAY, APRIL 29th

10:00 a. m. to 12:00 p. m. *East Lounge;* **Laboratory and Projection Session.**

Report of the Committee on Film Preservation; Capt. John G. Bradley, *Chairman.* (15 min.)

"A Film Emulsion for Making Direct Duplicates in a Single Step;" W. Barth and F. Schoeck, Agfa Ansco Corp., Binghamton, N. Y. (20 min.)

"Projection and Projectors;" A. J. Holman, East Orange, N. J. (20 min.)

"Some Properties of Motion Picture Film;" A. H. Nuckolls, Underwriters' Laboratories, Chicago, Ill. (20 min.)

"Action Is Needed;" F. H. Richardson, *Motion Picture Herald*, New York, N. Y. (10 min.)

2:00 p. m. to 5:00 p. m. Visits to the National Underwriters' Laboratories and other points of industrial interest.

7:30 p. m. *Ball Room;* **Semi-Annual Banquet.**

Addresses by eminent members of the industry, names to be announced later. Dancing and entertainment.

THURSDAY, APRIL 30th

10:00 a. m. to 12:00 p. m. *East Lounge;* **Slide-Film Symposium.**

"The Development of Slide-Film Stereopticons;" Miss Marie Witham, Society for Visual Instruction, Chicago, Ill. (15 min.)

"Slide-Films for Use in the Extension Division of the U. S. Department of Agriculture;" C. H. Hanson, Extension Service, U. S. Department of Agriculture, Washington, D. C. (*Demonstration.*) (20 min.)

"Visual Education and Slide-Films;" J. B. MacHarg, Lawrence College, Appleton, Wis. (*Demonstration.*) (20 min.)

"A Sound Slide-Film Projector;" F. Freimann, Electro-Acoustic Products Co., Fort Wayne, Ind. (*Demonstration.*) (15 min.)

"The Business Screen—Some Demands Made upon It;" W. F. Kruse, Bell & Howell Co., Chicago, Ill. (15 min.)

Report of the Committee on Non-Theatrical Equipment; R. T. Mitchell, *Chairman.* (15 min.)

2:00 p. m. to 5:00 p. m. *East Lounge;* **Apparatus and Equipment Session.**

"Photographic Race-Timing Equipment;" F. Tuttle and C. H. Green, Eastman Kodak Co., Rochester, N. Y. (15 min.)

"Use of Motion Pictures in an Accurate System for Timing and Judging Horse Races;" E. M. Honan, Electrical Research Products, Inc., Hollywood, Calif. (*Demonstration.*) (15 min.)

"Analysis of Sound Waves;" H. H. Hall, Cruft Laboratory, Harvard University, Cambridge, Mass. (15 min.)

"Copper Oxide Rectifier for Motion Picture Arc Supply;" I. R. Smith, Westinghouse Electrical & Manufacturing Co., East Pittsburgh, Pa., and C. E. Hamann, General Electric Co., West Lynn, Mass. (20 min.)

"A New Monitoring Telephone Receiver;" H. F. Olson, RCA Manufacturing Co., Inc., Camden, N. J. (15 min.)

"A New Rotary Stabilizer Sound Head;" F. J. Loomis and E. W. Reynolds, RCA Manufacturing Co., Inc., Camden, N. J. (15 min.)

"The Magazine Ciné-Kodak;" O. Wittel, Eastman Kodak Co., Rochester, N. Y. (10 min.)

"Demonstration of 16-Mm. 1000-W. Filmosound Projector;" R. F. Mitchell and W. L. Herd, Bell & Howell Co., Chicago, Ill. (15 min.)

ABSTRACTS OF PAPERS FOR THE CHICAGO CONVENTION APRIL 27–30, 1936

The Papers Committee submits the following abstracts of papers for the consideration of the membership. It is hoped that the publication of these abstracts will encourage attendance at the meeting and facilitate better discussion of the papers.

G. E. Matthews, *Chairman*

C. N. Batsel	M. E. Gillette	H. B. Santee
L. N. Busch	R. F. Mitchell	T. E. Shea
A. A. Cook	W. A. Mueller	P. R. von Schrott
L. J. Didiee		I. D. Wratten

Report of the Progress Committee; J. G. Frayne, *Chairman.*

The Progress Report for 1935 shows decided advances in both professional and amateur cinematography, in sound recording technic and equipment, as well as in sound reproducing systems, for general theatrical usage.

Outstanding in the field of cinematography, although restricted at present to the amateur field, is the new Kodachrome color-film. The year 1935 was also noteable for the extension of the three-color Technicolor system to feature production.

Several advances are reported in new silent cameras for professional work. A very interesting development has been the polarizing filter introduced by the Eastman Kodak Company, which should prove to be a great aid both in professional and amateur cinematography.

In the field of lighting, interesting developments are reported in connection with the new gaseous conductors, which threaten to revolutionize the field of lighting as well as to provide new light-sources for projection. New lens spots utilizing the Fresnel type of lens were introduced successfully in studio work this year.

Development of the push-pull method of recording received impetus following the demonstrations at the S.M.P.E. Convention at Hollywood. Considerable interest has been aroused by the announcement of RCA of the use of ultraviolet light in recording. New theater systems involving new methods of pulling film, as well as a new type of multi-cellular horn, commonly known as the Fletcher horn, have been offered to the public during the past year.

"The Museum of Modern Art Film Library;" John E. Abbott, *Director, The Museum of Modern Art Film Library,* New York, N. Y.

Until last year, no organization existed for preserving films of outstanding merit or for arranging for distribution and study by those interested in film as a living art and in its history and development. A grant from the Rockefeller Foundation, and private gifts, permitted The Museum of Modern Art to establish such a Film Library under the Presidency of John Hay Whitney, with Will H. Hays, Chairman of the Advisory Committee.

The functions of the Film Library are to trace, obtain, and preserve important films, American and foreign; to edit and assemble such films into programs for educational and non-commercial exhibition; to arrange notes and critical appraisals of such films; to assemble a library of books and data on the films; and, otherwise, to make available information concerning the artistic, dramatic, and technical phases to all who may be interested. The series for 1936 consists of (*1*) the development of narrative (1894–1911); (*2*) the rise of the American film (1912–15); (*3*) D. W. Griffith (Intolerance); (*4*) the German influence; (*5*) the talkies.

"The Application of Sound Motion Pictures to the Identification of Criminals;" Col. H. N. Schwarzkopf, *Superintendent, New Jersey State Police,* Trenton, N. J.

In June, 1934, in developing the principle of extending the applications of science to the solution of crime, the idea was conceived of reproducing the police "line-up" in sound motion pictures. Such a process would make a permanent record of what now is a passing incident; which record would be available not only to police departments but also for display to the public when necessity demands. After a period of research and study, experimentation with 16-mm. commercial sound motion picture apparatus was begun, with sufficiently satisfactory results to justify continuation and expansion.

In October, 1935, the entire matter was laid before engineers and technicians, with special recommendations for the development of 16-mm. and 35-mm. apparatus. As a result of this conference complete sets of equipment for 35-mm. and 16-mm. recording have been developed to the point that policemen, unskilled in recording technic, can accomplish uniform results satisfactory for criminal identification purposes.

This is a triumph for both the motion picture industry and the organized police; and as its use is extended it will result not only in speedier apprehension of habitual criminals, but will, likewise, unquestionably exercise a far-reaching preventive effect.

Report of the Sound Committee; P. H. Evans, *Chairman.*

Progress being made on the projects assigned to the Committee is discussed. These include the study of frequency response characteristics of release prints made by the use of the Sound Committee's frequency reference standard. The report will not include any conclusions or data relative to these projects.

"Photoelectric Cells and Their Method of Operation;" M. F. Jameson and T. E. Shea, *Bell Telephone Laboratories,* New York, N. Y.

This is an explanatory paper covering in a simple manner the laws governing the release of electrons from photoelectric surfaces, their collection at anodes, and the creation of ions in photoelectric cell gases by the "ionization" process. The paper deals with the spectral selectivity of various photoelectric surfaces, the influence of spectral characteristics of illumination, and the dynamic characteristics of vacuum and gas-filled cells. The paper will be accompanied by a demonstration of the various operating features of photoelectric cells.

"Harmonic Distortion in Variable-Density Records;" B. F. Miller, *Warner Bros. First National Studio,* Burbank, Calif.

This paper consists of two portions, the first being concerned with a derivation of the equations expressing the exposure wave-form on variable-density records obtained by means of the light-valve under conditions of sinusoidal ribbon modulation and known over-all photographic sound-track gamma. Curves indicating the theoretical percentage of second and third harmonic print distortion are plotted against frequency, several values of over-all gamma being assumed. It is shown that the distortion at low frequencies is almost exclusively due to departures of the over-all gamma from unity, while the distortions at high frequencies are mainly dependent upon the velocity of the light-valve ribbons.

The second portion of the paper is devoted to the presentation of experimental distortion data obtained from variable-density frequency data obtained from variable-density frequency films, and the comparison of these data against those obtained from theoretical analysis.

"Improved Resolution in Sound Recording and Printing by the Use of Ultraviolet Light;" G. L. Dimmick, *RCA Manufacturing Co., Inc.*, Camden, N. J.

The resolution of sound-film records has been increased by the use of ultraviolet light in recording and printing. Because of the absorption characteristics of the emulsion, exposures made by ultraviolet light are restricted to the surface. This reduces the spreading of the image. The fogging of the track that usually results from halation and reflection from objects in the path of the light is almost entirely eliminated. Since the light energy is restricted by means of a filter to a very narrow band, the chromatic aberration of the lenses is reduced.

The definition of the very fine recording light-beam is limited by diffraction. This limitation is materially decreased as a result of the decrease in wavelength of the radiant energy.

"The Acoustic Design of Music-Scoring Stages;" C. M. Mugler, *Acoustical Engineering Co.*, Los Angeles, Calif.

The design of the scoring stage built at Columbia Pictures Studio, at Hollywood, are described and discussed. The stage embodies an innovation in architectural and acoustic design based upon the "controlled reflections and diffusions of sound waves," discarding the "live and dead end" theory of acoustic design which has been greatly followed in the past.

"A High-Quality Reproducing System for Small Theaters;" H. Pfannenstiehl, E. O. Scriven, and J. F. D. Hoge, *Bell Telephone Laboratories*, New York, N. Y.

This sound reproducing system is intended particularly for use in small-sized theaters having seating capacities up to 600 persons. The sound pick-up part of the system consists of a sound head attachable to the various models of Simplex projectors. The film, after leaving the intermittent mechanism in the projector, passes through a chute in the sound head; then over a flywheel-controlled smooth roller, where the sound-track is scanned by an optical system; back to the hold-back sprocket in the projector, and thence to the take-up magazine. The sound-head contains no drive-sprocket mechanism.

The arrangement permits a very simple and easily operated film-drive control. A motor, belt-connected to the projector drive-gear and mounted upon a bracket that maintains the belt tension constant, drives the projector. The photoelectric cell in the sound head is transformer-coupled to an amplifier arranged for wall mounting. This amplifier is contained in a cabinet that includes also a rectifier for supplying current to the exciter lamp, to the exciting coils of the stage speakers, and to a monitoring loud speaker. A control cabinet arranged to be mounted upon the wall in front of the projector contains a gain control and apparatus for switching from one machine to the other. The control cabinet is operable from either projector position.

"The RCA Recording System;" B. Kreuzer, *RCA Manufacturing Co., Inc.*, Camden, N. J.

This paper deals with the newly designed RCA recording system. Photographs are included showing the constituent parts and complete assemblies, together with diagrams of the various types of installations. The performance of the equipment is discussed and a typical re-recording layout is shown. Design improvements resulting in higher quality and greater ease of operation are explained.

Report of the Projection Screen Brightness Committee; C. Tuttle, *Chairman.*

This report of the Committee will discuss the data that have been gathered concerning screen brightness, and which will be presented in a symposium to be published in the May issue of the JOURNAL. Points to be covered are the following: (*1*) What should be the brightness level? (*2*) What brightness can be achieved? and (*3*) Is standardization at this time desirable?

"The Motion-Picture Screen as a Lighting Problem;" M. Luckiesh and F. K. Moss, *Lighting Research Laboratory, General Electric Co.*, Cleveland, Ohio.

The motion picture on the screen is discussed as a visual task, and its lighting and that of its environs is approached in the manner recommended by the authors for all lighting problems. After choosing the proper quality of light, and after making the screen brightness as great as is practicable, the problem becomes chiefly one of quality of lighting or distribution of brightness in the visual fields. Various aspects of visibility and psychophysiological effects of seeing are discussed. The problem is divided into two parts: (*1*) The attainment of maximal visibility within the central field (the motion picture on the screen) without regard to the surroundings; and (*2*) the illumination of the surroundings in such a manner as to produce maximal comfort and minimal loss of visibility. The problem is unraveled from the usual entanglement of physiological optics, much of which is largely of academic interest rather than of practical importance. It is shown to be a problem of lighting, to be guided by the same concepts, principles, and knowledge embodied in the science of seeing as are other lighting problems. Suggestions are made for practical studies of the possibilities of evolving the lighting of the motion picture screen and its environs from its present primitive stage of purely localized lighting which is generally undesirable.

"Source Construction and Color of Light of Some Incandescent Lamps;" R. E. Farnham and R. E. Worstell, *General Electric Co.*, Cleveland, Ohio.

This paper discusses first the advantages of concentrating the source of gas-filled incandescent lamps. The various forms available and their application to optical systems and reflectors are shown.

Data regarding the temperature (color and maximum) of the various types of lamps are presented, and the similarity of the radiation of incandescent lamps to that of a Planckian radiator of suitable temperature is indicated. Curves showing the amount of light emitted at various wavelengths or colors for all lamps of interest to the motion picture industry are presented, in terms of both equal visual output and equal wattage.

A discussion of the energy in the ultraviolet region and the effect of glass bulbs and lenses concludes the paper.

"Present Trends in the Application of the Carbon Arc to the Motion Picture Industry;" W. C. Kalb, *National Carbon Co.*, Cleveland, Ohio.

The present trend in the application of the carbon arc to the needs of the motion picture industry is toward more extensive use of the high-intensity arc. This is true both in the theater and in the field of motion picture production.

The limitations of the low-intensity arc, both as to brilliancy and quality of light, are discussed and compared with like properties of the high-intensity arc. The needs of the small theaters for increased volume and improved quality of projection light having been met by the development of the a-c. high-intensity and Suprex arcs, the demands of the largest theaters for still more light for projection are now met by the new super-high-intensity arc.

The trends of projection lamp design as related to light upon the screen are briefly discussed. The paper covers also the new white-flame carbon arc for broadside illumination, the new Sun arcs and rotary spots designed to prevent interference with sound productions, and the application of the new super-high-intensity arc to background projection.

"Theory and Use of Photoelectric Exposure Meters;" A. T. Williams, *Weston Electrical Instrument Corp.*, Newark, N. J.

The theory of photoelectric exposure meters and its application toward determining correct exposure are discussed. In addition to the elementary theory of exposure and exposure meters, calibration data are presented in sufficient detail to enable the photographer or cinematographer to use the meter as a photographic tool with originality, avoiding the necessity of following stereotyped instructions or of considerable experimentation. Applications of the meter for black-and-white as well as for color photography are discussed.

"A 13.6-Mm. Super-High-Intensity Carbon for Projection;" D. B. Joy, *National Carbon Co.*, Fostoria, Ohio.

A new 13.6-mm. super-high-intensity carbon is described which will burn at currents as high as 190 amperes and which has a higher intrinsic brilliancy and a more uniform distribution of light across the crater face than the regular 13.6-mm. carbon rated at 120 to 130 amperes.

Tests comparing the light upon a projection screen from this new carbon and from the regular carbon show conclusively that the available light upon the screen has been increased by at least 30 per cent. The arc lamp used with these carbons must be properly designed to take care of the increased current and carbon consumption.

"A Film Emulsion for Making Direct Duplicates in a Single Step;" W. Barth and F. Schoeck, *Agfa Ansco Corp.*, Binghamton, N. Y.

Duplicates of positives or negatives can be made by the familiar process of exposure, standard development, and fixation of a single film without requiring second exposure and development, as in the case of amateur motion picture reversible film, or resort to the duplicate negative process. Contact printing is required with exposures about equal to those used in printing chloride photographic paper emulsions. The emulsion, although of silver bromide composition, is of an entirely different type from all other photographic emulsions, making use of the solarization effect for the first time in practical photography. Some commercial possibilities of the new type of emulsion are seen in the duplication of *x*-ray and other valuable transparency originals, aerial mapping, motion picture still picture printing, photo reproduction practice, and general commercial photography.

"Projection and Projectors;" A. J. Holman, East Orange, N. J.

Theaters should provide every facility for pleasing the patrons, who are the support not only of the theater but of the entire motion picture industry. Nothing is more important to the industry than projection; yet producers, directors, and exhibitors show little interest in new projectors.

Lantern-slide technic is described, and its relation to motion pictures pointed out. Questions are raised as to how the motion picture has improved in the last twenty-five years, and why; what further improvement can be hoped for; and why intermittent illumination should be eliminated. Comparison is made between intermittent and continuous screen illumination, both with black-and-white and with Technicolor pictures, discussing the subject of eye-strain, persistence of vision, and various advantages of the continuous screen image.

The single lens-wheel theater projector is described in detail. The objective comprises one fixed component and one lens-wheel, the latter being the only moving optical part of the projector. A sphero-cylindrical condenser system is used, and a simplified film-feeding mechanism with sound pick-up is located directly above the picture aperture. Improved fire-shutter control and film-movement stabilizer, an accurate gear-train reduced to four gears, and a new quick-action take-up are some of the features of the new projector. The optical system is designed for additive three-color projection, with optical economizer.

"Action Is Needed;" F. H. Richardson, *Motion Picture Herald*, New York, N. Y.

A recently published editorial by a well known writer in the industry is quoted, in which the importance of excellence in projection is stressed. The possibility is discussed of realizing beneficial results through the coöperation of the Society of Motion Picture Engineers; and the opportunity for educational work with the organization representing the projectionists is pointed out. The manner in which such educational work might be financed and carried on effectively is discussed.

"The Development of Slide-Film Stereopticons;" Miss Marie Witham, *Society for Visual Education, Inc.*, Chicago, Ill.

A description is given of the improvements made during the past ten years in single-frame Picturol equipment, and the development of the new SVE double-frame Picturol projectors is described for the first time.

"The Department of Agriculture's Experience in the Preparation and Use of Slide-Films;" C. H. Hanson, *Extension Service, U. S. Department of Agriculture*, Washington, D. C.

Because of the rapidly increasing popularity of slide-films and the small demand for glass lantern slides, the Extension Service of the U. S. Department of Agriculture is now preparing all its new illustrated lectures in slide-film form only.

In order that slide-films may serve their purpose most effectively, they must give a faithful reproduction of fine detail in full-tone photographs, and in the same film give a readily legible image of line-drawings, charts, or reading matter. The technical difficulties involved in making originals, negatives, and positives are numerous, and the full development of the art of making educational slide-films of the highest quality will not come until considerable research and educational work has been done.

The opinion is expressed that of the many problems awaiting solution, perhaps none is more important than that of evolving and establishing standards for the guidance of those engaged in planning and making original copies. Second, there is an urgent need for definite information as to the best materials and technic to use in making the negative and the positive. After ten years of experience in the production of slide-films, it is maintained, present equipment is ill suited to its purpose. Reasons are given, and a plea is made for the adoption of a larger aperture as standard and the design and manufacture of production and projection equipment of greater precision and adaptability.

"Visual Education and Film Slides;" J. B. MacHarg, *Lawrence College*, Appleton, Wis.

The value of pictorial helps in education was emphasized in the Middle Ages. The invention of lenses was soon followed by the stereopticon, but its usefulness was negligible until the introduction of photographic plates and powerful illuminants in the nineteenth century.

The invention of flexible film and Mazda light made possible film-strip slides having great advantages of convenience and cost. The necessity of a fixed series of slides introduces problems that have not been recognized in the production of much of the film-strip material now available. Definite principles should govern the production of film-strip sequences.

The many advantages of film-slides are as yet little known. Their convenience and negligible cost make their wider use desirable. At least three machines, adapted for this kind of slide, will soon be available.

Most film stereopticon positives now used in educational work are single-frame. The double-frame positive has some elements of superiority, and there is a great advantage in that equipment is available for its production by any advanced amateur.

The great problem of visual teaching is to supply apparatus and materials so efficient and so easy to use that they *will* be used. Film-strip and film-slides are the least expensive and most convenient of all devices for visual teaching by light projection. They open a broad field for important development.

"The Business Screen—Some Demands Made by and upon It;" W. F. Kruse, *Bell & Howell Co.*, Chicago, Ill.

The use of motion pictures for advertising has been with us for a number of years, but it has been only in the past few years that the use of the business film has reached such outstanding proportions. A major portion of such films is now shown on 16-mm. sound equipment. Some idea of the extent of growth of the business may perhaps be appreciated by considering that the Chrysler Corporation has allotted a major portion of its advertising allowance for the past two or three years to motion pictures. This is typical of many other organizations.

Some of the applications that have been made, and the various groupings into which the several types of advertising pictures fall, are described. A brief historical explanation is given as to why the various types of such films have come into use and the reasons why these applications are likely to be extended.

Specifications for the ideal sound projector as outlined by advertisers are briefly given, together with a brief comparison of what is available and how close it is to the ideal.

"Report of the Committee on Non-Theatrical Equipment;" R. F. Mitchell, *Chairman.*

Recent progress and development in the various fields employing non-theatrical motion pictures and equipment are outlined. These fields comprise principally industry and education. Great advances in the use of 16-mm. sound prints are reported, and the possibilities of this medium are shown to be achieving wide recognition.

The necessity for an S. M. P. E. 16-mm. sound test-reel is stressed, and some recommendations for preferred practice are made for the consideration of the Standards Committee.

"Photographic Race-Timing Equipment;" F. Tuttle and C. H. Green, *Eastman Kodak Co.*, Rochester, N. Y.

As a result of the need of greater accuracy in rendering decisions of racing events without appreciable delay, equipment was developed to permit viewing, within three minutes, paper enlargements made from 16-mm. motion picture negatives of the finishes. The general requirements for the early rapid processing machine and the machine itself are described, with sketches, and the early cameras and their requirements are also mentioned.

As a result of experience gained in the field with this equipment certain changes were found desirable. The design of the new camera is considered in detail, and illustrations of the camera and a finish of a race are shown. The new processing machine and its enlarging head are described, with illustrations of the assembled equipment.

"Use of Motion Pictures in an Accurate System for Timing and Judging Horse-Races;" E. M. Honan, *Electrical Research Products, Inc.*, Hollywood, Calif.

The installation and operation of an accurate system for timing and judging horse races at Santa Anita Park, Calif., are discussed. The equipment consists of photoelectric cells and associated exciter lamps placed around the rack at proper positions; a visual electric timing board placed in the infield; two electrically driven cameras associated with electrically driven clocks mounted in a booth above the grandstand exactly at the finish line; and connected to the cameras in a darkroom immediately behind them is a rapid film processing and printing equipment.

When the horses at the starting position interrupt the light-beam focused upon the photoelectric cell, an electrical impulse is transmitted to a central control cabinet mounted in the camera booth, and thence to the electric clocks associated with the cameras and to the rotary selector switches operating the electric timer in the infield. The time of each quarter-mile interval of the race is recorded visually on the electric timer.

Two special Eastman 16-mm. cameras are mounted exactly at the finish line. These cameras are equipped with a double-lens train: one to photograph the horses as they cross the finish line, and the other to photograph upon the same frame the reading of the electrically driven clock upon which the camera is mounted. The cameras are driven directly by synchronous motors, and may be operated at speeds ranging from 62 to 101 double frames per second. The electric clocks associated with the cameras are driven by crystal-controlled 200-cycle current. The clocks are started by the impulse from the first photoelectric cell in the race, and are stopped manually after the cameras are stopped. The cameras are operated manually to photograph the order and the time of the finish.

"Analysis of Sound Waves;" H. H. Hall, *Cruft Laboratory, Harvard University*, Cambridge, Mass.

Most sounds consist of a spectrum of frequencies of various intensities. The distribution of the frequencies and intensities determines the quality of the sound. The spectrum may remain fairly constant in time, or it may go through rapid changes. Sound analysis is the process by which the various components of the spectrum are detected and measured. A complete analysis should furnish the frequency and amplitude of each component as well as its phase relatively to the other components, at a given instant of time. If the spectrum changes in time, a complete analysis should be made at intervals throughout the duration of the sound, the lengths of the intervals being determined by the rate at which the spectrum is changing.

For purposes of analysis, sounds may be grouped into three classes: (*1*) Sounds that may be maintained at constant frequency, constant intensity, and unvarying quality for a period long enough to carry out the analysis; (*2*) sounds that are essentially transient in nature; (*3*) sounds that may be maintained constant, on the average, but whose frequency, intensity, and quality vary periodically within this time. The first two groups of sounds require different methods of analysis. The third group in certain instances may be analyzed by the methods used for class (*1*), while in other instances the method used for class (*2*) may be necessary.

Sound analysis may be made to yield valuable information concerning the source of the sound and the possibility of good transmission and reproduction. It furnishes also a measure of the quality of the sound. Methods of analysis and some results obtained are given. The analyzer built at the Cruft Laboratory is described, and examples of analyses made with it are presented.

"Copper Oxide Rectifiers for Motion Picture Arc Supply;" I. R. Smith, *Westinghouse Electric & Manufacturing Co.*, Pittsburgh, Pa.

The copper oxide rectifier approaches in many ways the ideal rectifier, having a combination of characteristics found in no other rectifier. These include long life, no moving parts, silent operation, and rugged construction. Although first applied in radio, since 1927 many industrial applications have been made. These include use in telephony, fire-alarm systems, operation of time clocks, circuit breakers and all types of contactors, and many other applications.

The rectifier is a resistance device, having negative temperature coefficient of resistance and a ratio of back to forward resistance of several thousand. Rectifiers can be built for any voltage and current output desired by paralleling the disks or connecting them in series, as required.

Ratings depend upon heat-radiating ability. Heat is dissipated by convection cooling, with large radiating fins. Resistance characteristics undergo change with time, the extent depending upon temperature and duty-cycles. Standard ratings are based upon the aged characteristics, not the new. Nine-year old life tests indicate an indefinite life, if properly applied. Fan cooling affords better heat dissipation, lowering the temperature of the units, permitting safe operation at higher outputs, and reducing size of the units. Large outputs, such as for arcs, can then be obtained from small rectifiers. The copper oxide rectifier appears to be finding acceptance in the motion picture industry as in other industrial applications.

"A New Monitoring Telephone Receiver;" H. F. Olson, *RCA Manufacturing Co., Inc.*, Camden, N. J.

A high-fidelity telephone receiver has been developed having uniform response over a wide frequency range. The new type of vibrating system compensates for the loss of low-frequency response due to the normal leak between the ear-cap and the ear. Uniform response is maintained at the high frequencies by employing a system having small effective mass reactance. Experimental data obtained on an artificial ear are presented, showing the effect of the acoustic leak upon the response of various types of telephone receivers. Subjective tests are also described and data given corrobrating the tests on the artificial ear.

"The Magazine Ciné-Kodak;" O. Wittel, *Eastman Kodak Co.*, Rochester, N. Y.

Unique points in the design of the magazine are the inclusion of a loop-maintaining sprocket, a protective metal shutter that automatically covers the film before the camera can be opened, and a film indicator that registers whether the machine is in or out of the Ciné-Kodak.

The camera itself, which is unusually compact, is operated by two spring motors that will drive the mechanism at 8, 16, or 64 frames per second. While the shutter is of the rotary type, it is conical in shape, to reduce camera thickness. The pull-down is of the ratchet type.

The one-inch $f/1.9$ lens is interchangeable with lenses of various focal lengths. A novel, practical finder system, which is combined with the carrying handle, provides correct fields for any of these lenses by sliding a negative element to various positions between the peepsight and the finder lenses.

"1000-Watt 16-Mm. Filmosound;" R. F. Mitchell and W. L. Herd, *Bell & Howell Co.*, Chicago, Ill.

A 16-mm. sound-film projector is described, incorporating many unusual features, such as stream-line base, 1000-watt lamp and *T-10* bulb, motor drive take-up and motor rewind, built-in film humidifier, and many other advanced ideas. A special amplifier and loud speaker have been developed for this equipment. The amplifier has an undistorted output of approximately 25 watts. Connections for two projectors enable a professional show to be put on.

The entire equipment, including cords, film, and accessories, is carried in two cases, the total weight being about 85 pounds. The equipment is used extensively for lecture work and for industrial presentations to audiences of a size ordinarily associated only with the smaller theaters. The paper concludes with some interesting acoustical data on the application of the equipment and the types of halls encountered in practice.

SOCIETY ANNOUNCEMENTS

ATLANTIC COAST SECTION

On February 19th, at a meeting held at the studio of RCA Photophone, Inc., New York, a paper by G. L. Dimmick on the subject of "Improved Resolution in Sound Recording and Printing by the Use of Ultraviolet Light," was presented by J. O. Baker. Following the paper was a presentation of a recording of selections from *The Eternal Road* made by the new system. The meeting was attended by nearly 400 persons, and considerable interest was shown in the presentation.

At a meeting on March 19th, held at the Bell Telephone Laboratories, New York, V. Subrizi presented a paper dealing with "Flutter in Sound Records," followed by a demonstration. This paper was presented previously at the Hollywood Convention last May, and was published in the November, 1935, issue of the JOURNAL. The meeting was well attended, and an interesting discussion ensued.

MID-WEST SECTION

Members of the Section were the guests of the Chicago Cinema Club at a meeting held at the plant of the Bell & Howell Company on March 12th. Prize-winning pictures in the *American Cinematographer* Amateur Contest were shown. The meeting was well attended, and much interest was shown in the presentations.

SOUND COMMITTEE

Plans for the 1936 report of the Committee were discussed at a meeting held at the General Office of the Society on February 21st. Further data obtained with the Frequency Reference Standard described in the previous report (published in the January issue of the JOURNAL, p. 21) were discussed, and an agenda established for the work of the year.

STANDARDS COMMITTEE

At a meeting held on February 20th at the General Office of the Society, further attention was given to the revision of the Standards Booklet, and steps were taken to begin work on the new drawings. Prior to the meeting, letter-ballots had been mailed to the members of the Committee for voting upon (*1*) the adoption of a reel capable of holding 2000 feet of film, for general use for release prints throughout the industry; (*2*) the specifications proposed for such a reel by the Academy of Motion Picture Arts & Sciences; and (*3*) the deletion from the Glossary of the Society of the definition of a "reel" as being "approximately 1000 feet of film."

The letter-ballots indicated unanimous approval of the three proposals, and, accordingly, members of the Society are requested to forward their comments on them to the General Office. All comments received from the membership must be considered by the Standards Committee before the proposals can be submitted to the Board of Governors for adoption as new S. M. P. E. standards.

Steps were taken to appoint a number of foreign members of the Society to membership upon the Committee, in order to assist the Committee in gathering information as to what the rest of the world is doing in motion picture standardization, and, conversely, to communicate to the standardizing bodies of the various countries the viewpoints of the S. M. P. E.

The Society regrets to announce the deaths of:

STANLEY A. PIERCE
November 15, 1935

L. M. DIETERICH
December 29, 1935

SAMUEL R. BURNS
March 5, 1936

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Volume XXVI **MAY, 1936** **Number 5**

CONTENTS

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

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See p. 592 for Technical Committees

THE PROBLEM OF THE PROJECTION SCREEN BRIGHTNESS COMMITTEE

The Projection Screen Brightness Committee was organized to prepare for the Standards Committee a recommendation of theater screen brightness. Compared to the multiplicity of problems confronting other committees of the Society, the single task of this Committee may appear simple. However, the problem is very complex, and its solution involves an attack based upon a knowledge of several different branches of optical science, principal among which divers fields are photometry, physiological optics, geometrical optics, and photography.

To facilitate the formulation of its recommendation, the Committee requested a number of experts in the various fields to prepare a group of papers which would help to answer the following questions:

(*1*) What does the motion picture audience desire as to picture brightness?

(*2*) What brightness is possible with existing materials and equipment?

(*3*) What measuring instruments and methods are available for the determination of brightness?

During the Fall, 1935, Meeting at Washington, D. C., the Society devoted one of its sessions to papers prepared at the invitation of the Committee. These papers, the general Society discussion, and other relevant material that the Committee has since been able to obtain are published in succeeding pages of this issue of the JOURNAL.

These contributions still leave us far short of a complete knowledge of the screen brightness problem, but it may be said without hesitation that the present issue of the JOURNAL contains the most nearly complete summation of data and opinions that is to be found anywhere in the literature.

In a subsequent issue, the Committee will lay before the Society a report dealing with the pros and cons of adopting a temporary screen brightness standard.

SCREEN BRIGHTNESS AND THE VISUAL FUNCTIONS*

E. M. LOWRY**

Summary.—*The known facts, as reported in the literature, regarding the visual functions, so far as they are influenced by the brightness of the projection screen and its surroundings in the motion picture theater, are reported. The elements of major importance in the visibility of objects are (1) the angular size of the detail to be discriminated; (2) the contrast or degree of difference of brightness between an object and its background; (3) the intensity of illumination; and (4) the exposure time.*

When viewing a motion picture, the projection screen and its environment constitute the visual field, and the perception of detail in the projected picture is the visual task that the eye is called upon to perform. Since we are primarily concerned with perception, the most important of the visual functions are the perceptual ones, which are: (1) the least amount of light that the eye can perceive, or its threshold sensitivity; (2) its ability to distinguish differences in brightness, or contrast sensitivity; (3) the perception of form, or visual acuity; (4) and the speed of vision. Each of these functions is discussed, together with the effect upon them of the external factors with which they are correlated.

The object of this paper is to present the known facts, as reported in the literature, regarding the visual functions so far as they are influenced by the brightness of the projection screen and its surroundings in the motion picture theater. Since the enjoyment of the entertainment offered depends for the most part upon the organs of vision, the importance of providing conditions conducive to maximal visual comfort will be unquestioned. In order that the motion picture engineer may provide such conditions, it is necessary that he have as complete knowledge as possible of the factors that govern the efficiency of the visual organs. The attention of the audience must necessarily remain fixed upon the projected picture for long periods and, therefore, it is of the utmost importance that the projection system of which the screen and its background are an integral part be so adjusted as to secure undivided appreciation of the picture presented.

The projection screen and its environment constitute the visual

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* Presented at the Fall, 1935, Meeting at Washington, D. C. Communication No. 575 from the Kodak Research Laboratories.

** Eastman Kodak Co., Rochester, N. Y.

field, and the perception of the detail in the projected picture is the visual task set for the eyes to perform. Therefore, a complete understanding of all factors that influence the operation of the visual functions is the first requisite to the provision of a satisfactory arrangement of illumination conditions, and, consequently, of the screen brightness.

We know that fundamentally radiant energy, possessing the appropriate wavelengths and intensities, is the governing factor in the operation of all visual functions. We do not, however, know completely the process by which radiant energy is transformed into visual sensation, and, therefore, the functional responses of the visual process are beyond our control except by the indirect method of adjusting the external factors with which they are correlated. These factors are the quantity, quality, and distribution of light, together with the length of time that the eye is exposed to their action. It is through the study and regulation of these factors that we may attain the maximum of visual efficiency.

Several years ago, when addressing a meeting of the Society of Illuminating Engineers, Dr. E. C. Crittenden remarked that, "man's eye and his sensations must remain the basis for the evaluation of light." It is upon such a basis that the problem of arriving at satisfactory screen brightness must be attacked. Dr. Troland,[1] in an exhaustive review of the literature, has summarized the majority of the data available up to 1925, and in this paper extensive use has been made of his work, for which acknowledgment is hereby given.

As already stated, we are primarily concerned with perception, and, consequently, for our purpose the most important of the visual functions are the perceptual ones, although the motor functions may not be entirely disregarded. It is fundamental to the problem that all the functions of the eye owe their initiation to light; but, as will appear later, the latitude of lighting conditions is a wide one. Because of this fact, it is natural that the first phenomenon to be considered is the ability of the eye to perceive light. The least amount of energy that the eye can perceive is dependent upon the sensitivity of the retina, and retinal sensitivity automatically adjusts itself for the brightness level to which it is exposed. That is to say, the threshold is influenced by the adaptation or intensity level by which the eye has been stimulated. As a consequence, the absolute threshold is reached only after complete dark adaptation. Under such conditions, the least perceptible quantity of energy is of the order of 4.2×10^{-9}

erg per second. This value is stated by Troland[1] to be a fair average based upon a large number of determinations by different observers.

For our purposes, the above-mentioned figure will have more significance if reduced to photometric terms. The transformation may be accomplished by employing what has been called the mechanical equivalent of light. As reported by Coblentz and Emerson,[2] and by Hyde, Cady, and Forsythe,[3] the most probable value of the mechanical equivalent may be assumed to be 0.00156 lumen per watt for the wavelength to which the eye is most sensitive, namely, about 556 mμ, or one watt should yield 641 lumens. Now, the energy value at the absolute threshold is 4.2×10^{-16} watt, and, therefore, its value in lumens is 2.7×10^{-13}. According to Troland, this value of the quantity of light striking the retina corresponds to 7.3×10^{-9} candle one meter from the eye, assuming a natural pupil.

To go a step farther, it is found that for foveal vision the threshold is dependent upon the total flux of energy entering the eye without regard to area, so that the brightness for threshold visibility, of an object of given size, may be computed. It has been calculated that, under conditions of dark adaptation, a square whose sides subtend an angle of 2 degrees at the eye must have a brightness of approximately two millionths of a foot-lambert if it is to be detected.

The unit of brightness adopted throughout this paper is the foot-lambert, defined as the brightness of a perfect diffuser emitting or reflecting one lumen per square foot. We may say that any surface whatever, when viewed in a definite direction, has a brightness of x foot-lamberts, meaning that the particular surface when so viewed has a brightness equal to that of a perfect diffuser emitting or reflecting x lumens per square foot. Upon such a basis, assuming more or less perfect diffusion, the product of the illumination in foot-candles incident upon a surface and the reflection factor of the surface is numerically equal to the brightness in foot-lamberts. Considerable confusion exists in the literature with respect to the unit of brightness, and for that reason an attempt has been made in this discussion to reduce all brightness values to the same unit, namely, the foot-lambert. To this end, a conversion factor has been applied to results given originally in millilamberts, and in those cases where the illumination is specified in foot-candles, a reflection factor of 0.80 has been assumed.

So far the results considered have been for the threshold of vision and dark adaptation. Let us examine the effect of adapting the eye to different brightness levels, because, due to the automatic adjustment of its sensitivity, the higher the incident intensity the lower the eye's sensitivity becomes. Nutting, Blanchard, and Reeves[4] quite carefully studied the effect of intensity level upon the threshold with a 5-degree test-field. Their results reveal the fact that, when plotted to a logarithmic scale, the threshold is proportional to the intensity to which the eyes are adapted. As applied to the problem of projection screen brightness, these data have the following significance: with the eyes completely adapted to a brightness of the screen of 10 foot-lamberts, they would be unable to detect a brightness of less than 0.033 foot-lambert if the screen illumination were suddenly removed. The fractional amount of the original intensity that can be detected decreases as the level is raised and reaches a minimal value at approximately 100 foot-lamberts. As the eye functions in the midst of its normal surroundings, it is continually directed from one point to another in the visual field, and the data given above show that the range of brightness is best at that point at which the eye is able to distinguish the smallest fraction of the brightness to which it has just previously been adapted. In 1929, the writer[5] studied this problem somewhat further from a slightly different angle and determined the extinction point for light with the eye adapted to a variety of brightnesses. This point was termed the *brightness of black* and has application to the present problem in the following way: If the eyes of the observer are again exposed, for example, to a field brightness of 10 foot-lamberts, then any point in the visual field, the brightness of which is not greater than 0.08 foot-lambert, will appear black.

Since the eye is not in any sense an accurate means of judging absolute intensity, its ability to distinguish differences in brightness is of considerably greater importance. This function is commonly known as *contrast sensibility*, and has been the object of investigation since the time of Bouguer,[6] in 1760. As it is accustomed to operate in everyday vision, the eye must discriminate between relative brightnesses. That is, the objects toward which the eye is directed emit or reflect light in varying amounts, and the eye is called upon to discriminate between these differences. In 1934, E. H. Weber, the founder of modern psychophysical methods, experimentally investigated the relation existing between physical stimuli and sensation, and formulated his findings in the statement that "the just-appreciable increase of stimulus bears a constant ratio to the original stimulus."[7]

Somewhat later, Fechner attempted to express sensations in quantitative units assuming that all just-noticeable increments in sensation were equal, and stated the law that "the sensation varied as the logarithm of the stimulus."[7] That is to say, over a wide range of intensities the increments of brightness sensation are determined by the ratios of the particular light intensities rather than by their absolute values. Even the men for whom the law is named were aware that there were limitations beyond which it did not hold, and Helmholtz[8] and many others have pointed out the fact that the fraction varies considerably with intensity but that there is a middle zone of intensities where the variation approaches a minimal value. The limits of this zone are a matter of considerable interest to us because they will be determined by the fineness of discrimination required.

In 1876, Aubert[9] studied the deviation from Fechner's law and found high sensibility between brightness levels of 3.2 and 13.2 foot-lamberts. Later, König and Brodhun[10] collected data, which were recalculated by Nutting[11], and showed maximal sensibility at about 16 foot-lamberts. Helmholtz,[12] Schirmer,[13] Simon,[14] Cobb and Geissler,[15] Nutting [11,16] Reeves,[17] Blanchard,[18] Schoute,[19] and others have all made studies of the relation between the power of brightness discrimination and brightness level. The average of some fourteen values computed by Troland[1] places the lower limit of the Fechner law at a value in the neighborhood of 5.6 foot-lamberts. Increasing the intensity by a factor of 10 makes but a slight increase in sensibility, and for that reason offers no advantage to vision with respect to this particular function. Luckiesh[20] places the best region for sensibility to brightness difference at about 10 foot-lamberts. Our conclusion, therefore, may safely be that the maximum of sensitivity to brightness difference lies within a range of 10 to 100 foot-lamberts. Within this range, the fractional difference is approximately $^1/_{100}$ of the adapting brightness. Besides the brightness to which the eye is adapted, as studied by Nutting,[11,16] Blanchard,[18] Reeves,[17] Petren,[21] and others, there are several factors that may affect the response to brightness differences. Among them are pupillary size, which controls the intensity of illumination falling upon the retina, and the size of the stimulus or test-field. The effect of the latter has been well demonstrated by Reeves,[17] who found that the smaller the test-spot the higher must be the intensity for maximal sensibility. French[22] also investigated the effect of stimulus size, and expressed his results by the equation $B = 1/\sqrt{d}$, where B is the per cent difference in brightness just distinguishable, and d is the angular diameter of the retinal image. Upon this basis, the maximum of sensitivity may be realized only when the visual angle is not less than 4.2 minutes.

The work of Dittmers,[23] Schjeldrup,[24] Cobb and Geissler,[15] Cobb,[25] Adams and Cobb,[26] Selfers,[27] Martin,[28] Emerson and Martin,[29] has emphasized the very marked effect exercised upon the discrimination threshold by the brightness of the surrounding field. Cobb[25] found that brightness contrasts between 1 and 0.1 (central/surrounding field) caused a very rapid decrease of retinal sensitivity when the central field subtended less than 30 degrees at the eye. The decrease, however, was small when the contrasts were 1 and 10 in the opposite direction. In general, therefore, a surrounding field brighter than the test-field is more detrimental than a darker one, and it is reasonable to conclude that when the brightness between the surrounding and the central fields is least the discrimination is best.

Since, as we have seen, a certain amount of light is necessary to produce the sensation of light, it should be obvious that details can not be recognized unless each element of the detail directs toward the eye sufficient light for its recognition. This function, commonly called *visual acuity*, is perhaps the most important of all the visual functions. The perception of the presence of an object is not limited by the size but only by the intensity of the light that it sends to the eye. However, the perception of form embodies another factor, namely, the disappearance of brightness difference because of the smallness of the pattern of the test-field. The reciprocal of such angular size is taken as a measure of visual acuity. While visual acuity must be dependent to a degree upon the absolute intensity, it goes farther than that, since it is necessary that the pattern itself remain visible. Beginning with Mayer in 1754, scientific studies of the dependence of visual acuity upon intensity have been made. Although the number of such studies has been great, the work of König[30] was undoubtedly the most painstaking. His results led him to express acuity in the form of a logarithmic law which held over a range of 0.0000025 to 53.2 foot-lamberts. At the latter point, the departure from the law is marked by a lack of further increase, although brightnesses went as high as 4320 foot-lamberts. Between 8 and 43 foot-lamberts, he found an increase of 31 per cent in acuity. Cobb and Geissler[15] also found a logarithmic relation between acuity and brightness for a range of from 0.0013 to 20 foot-lamberts. Cobb,[25] and then Dunlap,[31] made further studies with approximately the same results. Ferree and

Rand[32] found very little increase in acuity above 4 foot-lamberts, although there was some slight increase even at 20 foot-lamberts. Low intensities were found to be somewhat disadvantageous to eyes that were slightly defective, but at higher levels they appeared not very different from normal ones.

Averaging the results of all observers, Troland[1] arrived at a value of 5.2 foot-lamberts, beyond which further increases in brightness did not yield an appreciable gain in acuity. All the results included in this average used test-patterns that possessed maximal contrast. It has been pointed out several times, notably by Cobb and Moss,[33] that the angular specification of acuity has little significance unless the conditions under which the determinations were made were clearly specified. As an example, discrimination of form is very noticeably affected by the degree of contrast between the object and its background. It is further affected by the brightness level at which the test-object is examined, and also by the time of exposure, although the latter is not quite so important as the first two, since exposure times are relatively quite long. Kolbe,[34] Broca,[35] and others have investigated the effect of contrast in this connection, and Broca[35] found that, at an illumination of 4 foot-candles with a contrast of 15 per cent, the acuity was 90 per cent higher than for a contrast of zero. Cobb and Moss[33] conclude from their results that, within the limits of 1 to 100 foot-lamberts, visual angle 0.8 to 16 minutes, and for exposure times of 0.075 to 0.300 second, the four variables, brightness level, contrast (which includes glare), visual angle, and exposure time are mutually complementary. That is to say, a deficiency in one may be compensated for by an increase in one of the others. Luckiesh and Moss[36] have also found that for a given size of test-object the contrast necessary for visibility becomes less as the level of brightness increases. Their data show that, for a visual angle of 2.5 minutes, a contrast of 5 per cent is required for visibility with a brightness of 92.9 foot-lamberts. At a brightness of 0.93 foot-lambert, a contrast of 20 per cent is needed, or if only 5 per cent contrast is available, the angle must be 6 minutes.

Conner and Ganoung[37] have examined the course of foveal and parafoveal acuity at low background luminosity and for a number of degrees of contrast between test-object and background. Their results indicate that both foveal and parafoveal acuity bear a linear relation to the logarithm of the background luminosity and that contrast is a decided factor. The function increases continuously with increasing background luminosity for the brightness range covered, which was from 0.00013 to 1.0 lumen per square foot. With constant background luminosity, the acuity increases with contrast, but not quite so rapidly as in the former case. The linear relation between background luminosity and acuity has been substantiated by Lythgoe,[38] Kryswijk and Zwikker,[39] and others.

Ferree and Rand[40] have also recently investigated the relation between acuity and the intensity of light, both for normal and presbyopic observers. For a brightness range of 0.4 to 80 foot-lamberts, they found increases of 112 and 160 per cent, respectively, for the two classes of observers. Their results also disclose the fact, which has been largely overlooked, that increases in acuity are not pronounced for young eyes beyond 8 foot-lamberts, but that with advancing age eyes still show an increase at 80 foot-lamberts. These data clearly demonstrate that age has a very important influence upon the effect of the intensity of light upon clear vision.

Since patterns of low contrast necessarily involve brightness sensibility, it is entirely to be expected that an increase in intensity beyond the level governed by the laws of brightness sensibility *vs.* intensity is wasted. Hartridge [41] and others claim that acuity and the laws controlling it ultimately resolve themselves into a matter of brightness discrimination.

Bloom and Garten[42] and Broca[43] also have studied the effect of adaptation upon acuity, and have found that dark adaptation does not compensate for low illumination, and consequently does not provide for an acuity equal to that of the light-adapted eye. Pupillary size and time of exposure all have an effect, although slight. The influence of color upon acuity has been carefully investigated, and the conclusion reached that although there is a difference in favor of the region of the spectrum possessing maximal visibility, the difference is practically negligible so far as the common illuminants are concerned.

The effect of glare, which is a component of contrast and depends upon the distribution of light, in general reduces acuity, due to the production of local desensitization of the retina. Nutting's[11] analysis of glare upon the basis of pain or unpleasantness resulting from a light stimulus of high intensity, showed that the glare point so defined is proportional to the cube root of the brightness to which the eye is adapted. Cobb and Moss[44] find that discomfort due to a glare source is a function of its intrinsic brightness as well as of the intensity of illumination incident at the eye. They also find that the reduction of visibility by a glare source is greater as the source approaches the line of vision, affecting large objects of low contrasts more than small ones in which the contrast is high.

Speed of vision, or the ability of the eye to see quickly, is another of the perceptual functions with which we are concerned. Visual efficiency as based upon reaction time, and absolute brightness was placed by Johnson,[45] following a review of the available data, at field brightnesses between 1 and 2 foot-lamberts, provided the test-field was above threshold dimensions.

In 1834, Talbot[46] formulated the law that intermittent illumination of the retina yields a luminous impression that is determined by the average energy incident upon it. A large amount of data indicates that the speed with which any degree of visual excitation is approached will increase as the intensity of the stimulus is increased. How important this principle is in determining the illumination level for practical work depends upon an analysis of the actual operations involved; for instance, whether the eye is required to move quickly from one dark area to another in which certain details are brighter.

The persistence of visual sensation after removal of the stimulus has been recognized since early times. In fact Aristotle made use of the fact in an attempted explanation of dreams. D'Arcy[47] made probably the first serious attempt to measure the persistence of the image of an object, by determining the rate at which a burning stick must be whirled around in order that the impression would be that of a continuous circle of light. Modern technic, however, has refined this method by determining the critical frequency of flicker. Critical frequency is studied by measuring the speed with which a sectored disk must be rotated between a source of light and the eye in order that the sensation become that of a continuous light. That the degree of flicker and the rate of change of stimulus at which flicker disappears is a function of the absolute intensity has been definitely established from a large body of data. Ferry,[48] Porter [49] and Ives[50] have independently shown that the rate of alternation at which flicker disappears is proportional to the logarithm of the intensity. Lythgoe and Tansley[51] have measured the critical frequency of flicker for both the foveal and peripheral retina during the course of dark adaptation following adaptation to light, and also during the course of light adaptation following dark adaptation. Their conclusions were that the results of the critical frequency of flicker method were in good agreement with the performance of the eye when applied to other visual tasks.

In order to approach the ordinary conditions of vision, Cobb[52] introduced the use of confusion patterns in the test-field, and demonstrated that persistence of vision breaks down under certain conditions so that increased intensities offer no gain in sensibility. His conclusions were that, for the conditions existing in his experiments, visual efficiency is improved up to brightnesses of the order of 32 foot-lamberts. Luckiesh[53] studied the speed of reading and found an average increase of 15 per cent for illuminations between 4 and 16 foot-candles, when the test was, as is the usual case, for black type upon white paper. With black printing upon gray paper having a reflection factor of 22 per cent, the result was an increase in speed of 50 per cent for the same brightness range. Ferree and Rand[54] have found quite large increases in speed of vision with increasing illumination and a proportionately greater gain as the angular size of the object diminished. The perception of motion, a close ally of speed of vision, involves a combination of space discrimination and changes in the intensity of stimulation at given points of the retina. Basler[55] found a progressive increase in motional acuity up to 8.8 foot-lamberts.

All available information shows that the voluntary functions of the eyes, such as accommodation, convergence, and fixation, do not require high intensities. As evidence of this, Israel[56] found that the average error in accommodation was $^1/_{23}$ of the total distance for a brightness of 0.00936 foot-lambert, and that, for both convergence and accommodation, it was about $^1/_{58}$ of the distance. Although accommodation breaks down at very low intensities, both convergence and fixation continue to the absolute threshold, which it will be remembered is 7.3×10^{-10} candle one foot from the eye.

The threshold for the involuntary contraction or expansion of the pupil was found by Engelking [57] to be about 0.0024 foot-lambert. Reeves'[58] measurements show that the pupil continues to contract up to brightnesses of at least 1000 foot-lamberts, the extremes being from 8 to 2 mm. Recent measurements by Luckiesh and Moss[59] of the pupillary light reflex place the minimum of pupil area to be reached for a field brightness of 465 foot-lamberts and a 17-degree field. Their measurements were made with fixation at the center of a bright field amid dark surroundings. The area and brightness of the field were varied, but the illumination at the eye was always kept constant at 10 foot-candles. Under such conditions, they found that the pupil area increased by 20 to 30 per cent for a brightness change of 37 to 12,077 foot-lamberts.

While the data that have been presented by no means exhaust the tremendous literature pertaining to vision, they do, however, give us a picture of the situation as regards the elements of major importance in the visibility of objects. The most important factors may be summarized as follows: (*1*) the angular size of the detail to be discriminated; (*2*) the contrast or degree of difference of brightness between the object and its background; (*3*) the intensity of illumination; and (*4*) the exposure time, although this is of little significance in the majority of cases. Almost all the studies that have been made have depended upon threshold methods for the determination of visual response. While such procedure is valuable, it does not provide us with the means of determining the ideal conditions for maximal visual efficiency. As Luckiesh has said in one of his papers: "From the standpoint of seeing, threshold data are of relatively little importance because we are seldom called upon to exercise the limits of visual acuity."

No information is available upon the visual functions as they operate while a motion picture is being viewed. Therefore, before any sort of justifiable recommendation may be made concerning the optimal arrangements for visual comfort and efficiency in viewing motion pictures, data must be obtained under conditions simulating those that exist in the practical situation.

(*For discussion, see p. 518*)

REFERENCES

[1] TROLAND, L. T.: "An Analysis of the Literature Concerning the Dependence of Visual Functions upon Illumination Intensity," *Trans. Illum. Eng. Soc.*, **26** (Feb., 1931), No. 2, p. 107.

[2] COBLENTZ, W. W., AND EMERSON, W. B.: "Luminous Radiation from a Black Body, and the Mechanical Equivalent of Light," *Bull. U. S. Bur. Standards*, **14** (1918–19), No. 2, p. 255; Scientific Paper No. 305 (June 30, 1917).

[3] HYDE, E. P., FORSYTHE, W. E., AND CADY, F. E.: "A New Experimental Determination of the Brightness of a Black Body, and of the Mechanical Equivalent of Light," *Phys. Rev.*, **13** (Jan., 1919), No. 1, p. 45.

[4] NUTTING, P. G.: "Effects of Brightness and Contrast in Vision," *Trans. Illum. Eng. Soc.*, **11** (Dec., 1916), No. 9, p. 939.

[5] LOWRY, E. M.: "Some Experiments with Binocular and Monocular Vision," *J. Opt. Soc. Amer. & Rev. Sci. Inst.*, **18** (Jan., 1929), No. 1, p. 29.

[6] "Traité d'optique sur la gradation de la Lumière," *Lacoille*, Paris, 81.

[7] PARSONS, J. H.: "Color Vision," *Cambridge Psychol. Library*, 2nd ed. *G. Pitman's Sons*, New York (1924), p. 22.

[8] Helmholtz, H.: "Handbuch der physiologischen Optik," Vol. II (English Translation), *Opt. Soc. of America* (1924), p. 178.

[9] Aubert, H.: "Grundzüge der physiologischen Optik," Handbuch der gesammten Augenblick Graefe u. Saemisch II, Tl. 2, p. 488.

[10] Experimental Untersuchungen über die psychophysische Fundamentformel in Bezug auf den Gesichtssinn. Sitzber. *Akad. zu Berlin* (1888), p. 917.

[11] Nutting, P. G.: "The Retinal Sensibilities Related to Illuminating Engineering," *Trans. Illum. Eng. Soc.*, **11** (Feb., 1916), No. 1, p. 131.

[12] Helmholtz, H.: "Die Störung der Wahrnehmung Kleinster Helligkeitsunterscheide durch das Eigenlicht der Netzhaut," *Zeitschr. für psychol.*, **1** (1890), p. 5.

[13] Schirmer, O.: "Über die Gültigkeit des Weber'schen Gesetze, für den Lichtsinn," *Graefe Arch. f. Ophthal.*, **36** (1890), p. 121.

[14] Simon, R.: "Über die Wahrnehmung von Helligkeitsuntercheiden," *Zeits. f. Physchol.*, **21** (1899), p. 433.

[15] Cobb, P. W., and Geissler, L. R.: "The Effect on Foveal Vision of Bright Surroundings," *Psychol. Rev.*, **20** (1913), p. 425.

[16] Nutting, P. G.: "Effects of Brightness and Contrast in Vision," *Trans. Illum. Eng. Soc.*, **11** (Dec., 1916), No. 9, p. 939.

[17] Reeves, P.: "The Effect of Size of Stimulus on the Contrast Sensibility of the Retina," *J. Opt. Soc. Amer.*, **1** (Sept., 1917), No. 5, p. 148.

[18] Blanchard, J.: "The Brightness Sensibility of the Retina," *Phys. Rev.*, **11** (Feb., 1918), No. 2, p. 81.

[19] Wertheim-Salomonson, J. K. A., and Schoute, G. J.: "Psycho-optische Untersuchungen. Über den Ausammenhang zwischen dem Reizungs gesetze und dem Gesetze Weber-Fechners," *Arch. f. d. ges. Physiol.*, **105** (1904), p. 389.

[20] Luckiesh, M.: "Light and Work," *D. Van Nostrand*, N. Y., (1924), p. 296.

[21] Petren, K.: "Ueber die Bezichungen zwischen der Adaptation und der Abhängigkeit der relativen Unterschiedsempfindlichkeit von der absoluten Intensität," *Skand. Arch. f. Physiol*, **15** (1904), p. 72.

[22] French, J. W.: "The Unaided Eye," *Trans. Opt. Soc. of Amer.*, **20** (April, 1918–1919), No. 7, p. 209; **21** (1919–1920), pp. 1, 127.

[23] Dittmers, F.: "Über die Abhängigkeit der Unterschiedschwelle für Helligkeiten von der antagonistischen Induktion," *Zeits. f. Sinnesphysiol.*, **51** (1920), p. 214.

[24] Schjelderup, H. K.: "Über eine vom Simutankontrast verschiedene Wechselwirkung der Sehleldstellen," *Zeits. f. Sinnesphysiol.*, **51** (1920), p. 176.

[25] Cobb, P. W.: "The Effect on Foveal Vision of Bright Surroundings, II," *Psych. Rev.*, **21** (1914), p. 23; *J. Exp. Psychol.*, **1** (1916), p. 540.

[26] Adams, E. Q., and Cobb, P. W.: "The Effect on Foveal Vision of Bright (and Dark) Surroundings, V," *J. Exper. Psychol.*, **5** (Feb., 1922), No. 1, p. 39.

[27] Seifers, K.: "Experimentelle Beitrage zur Untersuchung der Abhängigkeit der Unterchiedsschwelle für Helligkeiten von antagonistischen Induktion," *Zeits. f. Sinnesphysiol.*, **53** (1922), p. 255.

[28] Martin, L. C.: "The Photometric Matching Field," *Proc. Roy. Soc. A.*, **104** (Sept., 1923), No. *A*725, p. 302.

[29] Emerson, S. A., and Martin, L. C.: "The Photometric Matching Field, II, The Effect of Peripheral Stimulation of the Retina on the Contrast Sensi-

bility of the Fovea," *Proc. Roy. Soc.* (London) **108A** (July, 1925), No. *A*747, p. 483.

[30] König, A.: "Die Abhängigkeit der Sehscharfe von der Beleuchtungsintensitat," *Gesammeite Abhandlungen zur Physiol. Optik,* Leipsig (1903), p. 378–389.

[31] Dunlap, K.: "A New Measure of Visual Discrimination," *Psychol. Rev.,* **22** (1915), p. 28.

[32] Ferree, C. E., and Rand, G.: "The Effect of Variations in Intensity of Illumination on Functions of Importance to the Working Eye," *Trans. Illum. Eng. Soc.,* **15** (Dec., 1920), No. 9, p. 769.

"The Effect of Intensity of Illumination on the Acuity of the Normal Eye and Eyes Slightly Defective as to Refraction," *Amer. J. Psychol.,* **34** (1923), p. 244.

[33] Cobb, P. W., and Moss, F. K.: "The Four Variables of the Visual Threshold," *J. Frank. Inst.,* **205** (June, 1928), No. 6, p. 831.

[34] Kolbe, B. L.: "Ueber den Einfluss der relativen Helligkeit und der Farbe des Paders auf die Sehscharfe," *Arch. f. d. ges. physiol.,* **37** (1885), p. 562.

[35] Broca, A.: "Sur les causes de variation de l'acuité visuelle," *Soc. Franç. Phys. Bull.,* **159** (1901), p. 12.

[36] Luckiesh, M., and Moss, F. K.: "The New Science of Seeing," *Trans. Illum. Eng. Soc.,* **25** (Jan., 1930), No. 1, p. 15.

[37] Conner, J. P., and Ganoung, R. E.: "An Experimental Determination of the Visual Thresholds at Low Values of Illumination," *J. Opt. Soc. Amer.,* **25** (Sept., 1935), No. 9, p. 287.

[38] Lythgoe, R. J.: "The Measurement of Visual Acuity," *Medical Research Council,* Special Report No. 173 (1932), London, H.M.S.

[39] Kruyswijk, M., and Zwikker, C.: "Acuity of Vision as a Function of Brightness," *Physica,* **1** (1934), p. 225.

[40] Ferree, C. E., and Rand, G.: "The Effect of Intensity of Illumination on the Near Point of Vision and a Comparison of the Effect for Presbyopic and Non-Presbyopic Eyes," *Trans. Illum. Eng. Soc.,* **28** (July, 1933), No. 7, p. 590.

Ferree, C. E., Rand, G., and Lewis, E. F.: "Effect of Increase of Intensity of Light on Visual Acuity of Presbyopic and Non-Presbyopic Eyes," *Trans. Illum. Eng. Soc.,* **29** (April, 1934), No. 4, p. 296.

[41] Hartridge, H.: "Visual Acuity and the Resolving Power of the Eye," *J. Physiol.,* **57** (1922), p. 52.

[42] Bloom, S., and Garten, S.: "Vergleichende Unterschungen der Sehscharfe des Hell-und des Dunkel-adaptierten Auges," *Arch. f. d. ges. Physiol.,* **72** (1898), p. 372.

[43] Broca, A.: "Causes retimennes de l'acuité en visuelle lumière blanche," *J. Physiol. Path. Gen.,* Paris, **3** (1901), p. 384.

[44] Cobb, P. W., and Moss, F. K.: "Glare and the Four Fundamental Factors in Vision," *Trans. Illum. Eng. Soc.,* **23** (Nov., 1928), No. 11, p. 1104.

[45] Johnson, H. M.: "Reaction-Time Measurements," *Psychol. Bull.,* **20** (Oct., 1923), No. 10, p. 562.

"Speed, Accuracy, and Constancy of Response to Visual Stimuli as Related to the Distribution of Brightnesses over the Visual Field," *J. Exp. Psychol.,* **7** (1924), p. 1.

[46] TALBÔT, H. F.: "Experiments on Light, II, on Photometry," *Phil. Mag.*, 5 (1834), p. 327.

[47] D'ARCY: "Sur la durée de la sensation de la vue," *Mem. de l'Acad. des Sci.*, 1765, p. 450.

[48] FERRY, E. S.: "Persistence of Vision," *Amer. J. Sci.*, 3rd Ser. **144** (1892), p. 192.

[49] PORTER, T. C.: "Contributions to the Study of Flicker," *Proc. Roy. Soc.* (London), **63A** (1898), p. 347.

[50] IVES, H. E.: "Studies in the Photometry of Lights of Different Colors, I," *Phil. Mag.* (ser. 6), **24** (July, 1912), No. 139, pp. 149; **24** (Sept., 1912), No. 141, p. 352; **24** (Dec., 1912), No. 144, p. 845.

[51] LYTHGOE, R. J., AND TANSLEY, K.: "The Adaptation of the Eye: Its Relation to the Critical Frequency of Flicker," *Medical Research Council*, Special Report Series No. 134, London, H.M.S.

[52] COBB, P. W.: "The Momentary Character of Ordinary Visual Stimuli," *Psychol. Bull.*, **17** (Feb., 1920), No. 2, p. 44.

"The Relation between Field Brightness and the Speed of Retinal Impression, I and II," *J. Exp. Psychol.*, **6** (1923), p. 138; **8** (1925), p. 77.

"Some Experiments on the Speed of Vision," *Trans. Illum. Eng. Soc.*, **19** (Feb., 1924), No. 2, p. 150.

"The Meaning of 'Speed of Vision,'" *Trans. Illum. Eng. Soc.*, **20** (March, 1925), No. 3, p. 253.

[53] LUCKIESH, M.: "Discussion of Cobb's Paper on 'The Speed of Vision,'" *Trans. Illum. Eng. Soc.*, **19** (Feb., 1924), No. 2, p. 164.

[54] FERREE, C. E., AND RAND, G.: "The Effect of Variation of Visual Angle, Intensity, and Composition of Light on Important Ocular Functions," *Trans. Illum. Eng. Soc.*, **17** (Feb., 1922), No. 2, p. 69.

[55] BASLER, A.: "Über das Schen von Bewegungen, VII, Der Einfluss der Helligkeit auf das Eikennen Kleiner Bewegungen," *Arch. f. d. ges. Physiol.*, **199** (1923), p. 457.

[56] ISRAEL, H. E.: "Accommodation and Convergence under Low Illumination," *J. Exp. Psychol.*, **6** (1923), p. 223.

[57] ENGELKING, E.: "Die Schwellenwert der Pupillenreaktion und seine Beziehungen zum Problem der Pupillomotorischen Aufnahmeorgane," *Zeitschr. für Sinnesphysiol.*, **50** (1919), p. 319.

[58] REEVES, P.: "The Effect of Various Physical Stimuli on the Pupillary Area and Retinal Sensibility," B. J. **64** (Aug., 1917), No. 2988, p. 415.

"The Rate of Pupillary Dilation and Contraction," *Psychol. Rev.*, **25** (1918), p. 330.

"The Response of the Average Pupil to Various Intensities of Light," *J. Opt. Soc. Amer.*, **4** (March, 1920), No. 2, p. 35.

[59] LUCKIESH, M., AND MOSS, F. K.: "Area and Brightness of Stimulus Related to the Pupillary Light Reflex," *J. Opt. Soc. Amer.*, **24** (May, 1934), No. 5, p. 130.

MISCELLANEOUS REFERENCES

COBB, P. W.: "Vision as Influenced by the Brightness of Surroundings," *Trans. Illum. Eng. Soc.*, **8** (1913), p. 292.

EMERSON, S. A., AND MARTIN, L. C.: "The Photometric Matching Field, II. The Effect of Peripheral Stimulation of the Retina on the Contrast Sensitivity of the Fovea," *Proc. Roy. Soc.*, **108** (July, 1925), No. *A*747, p. 483.

LUCKIESH, M., AND MOSS, F. K.: "The Rate of Visual Work on Alternating Fields of Different Brightnesses," *J. Frank. Inst.*, **200** (Dec., 1925), No. 12, p. 731.

HOLLADAY, L. L.: "The Fundamentals of Glare and Visibility," *J. Opt. Soc. Amer.*, **12** (April, 1926), No. 4, p. 271.

"Action of a Light-Source in the Field of View in Lowering Visibility," *ibid.*, **14** (Jan., 1927), No. 1, p. 1.

LUCKIESH, M.: "Defining Glare and Visibility," *J. Frank. Inst.*, **203** (May, 1927), No. 5, p. 715.

COBB, P. W., AND MOSS, F. K.: "The Effect of Dark Surroundings upon Vision," *J. Frank. Inst.*, **206** (Dec., 1928), No. 12, p. 827.

ARNDT, W.: " 'Seeing' by Colored Light," *Zeits. f. techn. physik.*, **15** (1934), No. 8, p. 296.

LUCKIESH, M., AND MOSS, F. K.: "Dependence of Visual Acuity upon Stimulus-Distance," *J. Opt. Soc. Amer.*, **23** (Jan., 1933), No. 1, p. 25.

LUCKIESH, M., AND MOSS, F. K.: "The Human Seeing Machine," *J. Frank. Inst.*, **215** (June, 1933), No. 6, p. 629.

HECHT, S., AND VERRIJP, C. D.: "The Influence of Intensity, Color, and Retinal Location on the Fusion Frequency of Intermittent Illumination," *Proc. Nat. Acad. Sci.*, **19** (May, 1933), No. 5, p. 522.

COBB, P. W.: "The Dependence of Flicker on the Dark-Light Ratio of the Stimulus Cycle," *J. Opt. Soc. Amer.*, **24** (April, 1934), No. 4, p. 107.

HARDY, LEG. H.: "The Eye as Affected by Illumination," *Trans. Illum. Eng. Soc.*, **29** (May, 1934), No. 5, p. 364.

LUCKIESH, M., AND MOSS, F. K.: "Quality of Lighting," *Trans. Illum. Eng. Soc.*, **30** (1935), p. 531.

AN EXPERIMENTAL INVESTIGATION OF PROJECTION SCREEN BRIGHTNESS*

I. CHOICE OF THE AVERAGE OBSERVER

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Summary.—*An account is given of an experimental device by means of which an observer is enabled to control and select the brightness at which he wishes pictures to be projected. Data are given for the selections of thirteen individuals on five typical motion picture prints. It is concluded that (1) the average selected brightness is about 30 foot-lamberts; (2) individual observers differ by a factor of 3; (3) a border brightness of 0.05 foot-lambert is preferable to a dark border.*

Few will denv that the brightness to which a motion picture screen is illuminated is of importance both to the comfort and the visual welfare of an observer, yet there appear to be no satisfactory psychophysical data upon which a recommendation of screen brightness can be based.

It is known that visual acuity increases with brightness until a level of more than 10 foot-lamberts is reached. For increase of brightness above this value, visual acuity changes but little. Similarly, it is known that the Weber-Fechner fraction (least perceptible contrast, *i. e.*, change in brightness expressed as a fraction or percentage) decreases with increase of brightness until a level of about 25 foot-lamberts is reached, above which level it too remains substantially constant over a wide range. It is known that continued use of the eyes in attempting to discern fine detail near the limit of visual acuity, or, to a lesser extent, to discern brightness differences near the limit of the Weber-Fechner fraction, results in fatigue. For lack of a better term, this is called "visual fatigue," although little is known of its exact nature. From the foregoing it is evident that the finer the detail or the smaller the steps of brightness to be viewed, the greater must be the brightness level, if fatigue effects are to be reduced to a minimum.

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But there are more factors than these determining the optimal brightness of a projection screen. Too great a contrast (too great a range of brightness) results in an unpleasant sensation that is not well understood but is usually reported as "glare," although the term may be misapplied in this connection. Thus, while brightness may offset low contrast, too high a contrast as a remedy for low brightness may bring worse evils than it cures.

The immediate surroundings of a screen may influence the optimal brightness. Present projection practice provides, almost universally, a dark screen border of no measurable brightness compared to that of the screen itself, and so it may be argued that border conditions are at least constant. However, nearly everyone who has worked upon the physiology of vision will condemn this practice, upon the basis of eye fatigue or even injury. It is well known among ophthalmologists and others concerned with the care of the eyes that reading or other close work with high central but low peripheral illumination produces eye-strain which may be relieved simply by increasing the peripheral illumination without changing the brightness of central objects.

While there is no satisfactory explanation for this need for border illumination, we must accept it as an empirical fact, and be prepared for changes in projection practice that may involve a border brightness that is low, but not negligible, as compared to the brightness of the screen.

Viewing motion pictures may be regarded as a visual task, and from analogy with other visual tasks, one might arrive at some recommendation of screen brightness. It is known that such a task as reading fine print is made easier by increasing the brightness up to 10 foot-lamberts, and in some cases, higher. This is a task requiring high visual acuity, but is usually one in which the brightness contrast between the paper and the print is great. Similarly, tasks involving a fair degree of visual acuity at low contrast, such as is encountered in certain types of sewing, are known to be lightened by a brightness increase to 10 foot-lamberts or beyond. From this it might be argued that the task of viewing motion pictures would be lightened if the brightness were maintained at a level similar to that cited above, since here fair visual acuity is frequently required and the contrast is sometimes low.

But in viewing motion pictures additional factors complicate the visual process. Chief among these is motion, which at times is rapid.

Moreover, the motion is not continuous but intermittent, as is the illumination, and this has been assumed by some to be another source of fatigue. However, it may well be that with modern projection systems and projection speed, neither the discontinuous character of the motion nor the intermittent illumination are of first importance, and that viewing the moving image presents a no more arduous visual task than viewing the original moving object. Even so, the motion itself adds another burden to the visual mechanism.

It is not known how much additional burden this element of motion may involve, nor are data available from which to draw any very satisfactory conclusions regarding this point. Experiments have been made with visual tasks that require observing movements such as those of serving a punch or printing press, semi-automatic folding or packaging operations, and many other examples encountered in industry. Also specially devised visual tasks of this character have been used for laboratory observation, and numerous reports upon eye performance under such conditions appear in the literature. But we can glean little information from these which can be applied to our present problem other than that adequate illumination lessens the visual task, as shown both by comfort of the worker and objective evidences of fatigue. There is some disagreement as to what constitutes "adequate illumination," but again most writers are agreed that a level of 10 foot-lamberts represents the lower brightness limit, while some recommend 50 or even 100 foot-lamberts for close work upon a moving object.

Obviously, more direct experimental data are needed upon the relation of brightness to the task of viewing motion pictures. Objective studies of an observer's visual functions before, during, and after viewing motion pictures are difficult to interpret. It has seemed to us that a more direct attack would be to determine the observer's choice of brightness level for viewing a representative group of motion picture scenes, placing in his hands the means of varying the scene brightness easily and rapidly over limits so wide as to include the choice of practically any observer.

It may be argued that an observer's choice of brightness level is not necessarily the best brightness level from the point of view of reducing fatigue and safeguarding the observer's visual apparatus. Our desires or instincts are not always accurate indexes of what is best for our welfare. A choice of foods, for example, based upon appetite, is not always best suited to digestive welfare, and many similar cases might be cited. But it must be remembered that, in the case of eating, pleasure may be very directly associated with the act itself. The pleasure derived from viewing a motion picture, on the contrary, is the result of complex perceptions which follow but are not a part of, the visual experience. The eyes are called upon to do work from which the observer may derive pleasure, just as the teeth and jaws are called upon to do work in the process of eating. The pleasure derived from eating is not ordinarily associated with the act of chewing.

For these reasons, it seems to us highly probable that a subject who has control of the brightness of a projection screen while he observes, will select the level that will result in the least visual effort necessary to register all the details of the scene that he desires to see.

The ideal "apparatus" to gather the data that we wish to obtain would be a typical modern theater equipped with projection equipment capable of furnishing more light than any observer could care for. Unfortunately, this is many times the amount of light that even the most efficient equipment can now deliver. With this hypothetical super-projector would be associated some device by means of which an observer seated in the theater could regulate the screen brightness to suit himself.

For our actual apparatus, we have been forced to make a number of concessions in order to make the experiment practical. We have made the screen small, in order to achieve great maximal brightness, and have used 16-mm. film because of its greater convenience. Other deviations from practical theater conditions will be obvious in the following description of the apparatus.

A model *L* Kodascope capable of delivering about 200 screen lumens has been equipped with a rather nice mechanism for remote control of the illumination that it delivers to the screen. In front of the objective is placed a neutral optical wedge fourteen inches in length, the transmission of which varies continuously from end to end. The wedge is supported upon a carriage with roller bearing wheels. To the carriage is attached a long rack which engages the pinion of a small reversible motor. By means of a suitable pushbutton connection to the motor, the observer is able to control the wedge position, and hence the screen brightness, from any chosen part of the "auditorium." The speed of movement of the wedge is such that it varies the screen brightness by the ratio of 100 to 1.0 in about four seconds. The movement is silent and steady. It can be instantly stopped or reversed, so that the operator really has a nice method of photometric control at his finger tips. At the extremes of the range, the picture is either much too bright or much too dark, so the observer seldom allows the wedge carriage to travel to the end. When this does happen, however, no harm is done, because the motor, which is a Barber-Colman shaded-pole model, is not damaged by stalling.

Film is fed to the projector and taken up with a repeater supply magazine which will handle 140 feet of print or less.

A translucent screen is mounted upon a box framework as shown in cross-section in Fig. 1. Within the box is a masking partition for the picture itself. Around this partition are located banks of lamps which supply border illumination for the picture. Viewed from the front, the picture (30 × 22$^1/_2$ inches) is located in the center of the illuminated border. The dimensions of the border, which forms a hollow rectangle around the picture area, are 72 × 54 inches.

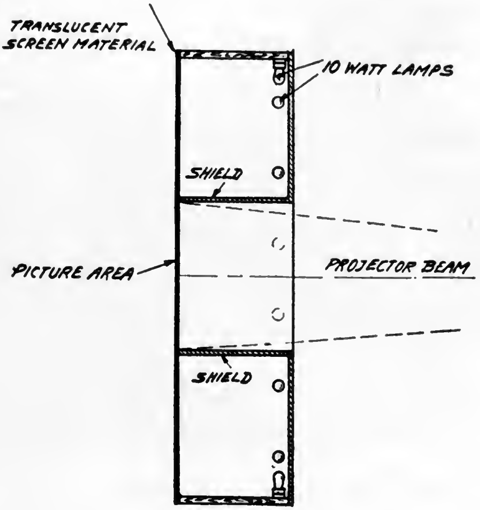

FIG. 1. Cross-section of screen frame and border lamp housing.

Gathering the experimental data was greatly facilitated by automatic recording, which is accomplished by the apparatus shown in Fig. 2. A 35-mm. motion picture camera is focused upon a panel board containing a scale connected to the brightness-regulating wedge carriage; an ammeter which measures the current and therefore the illumination of the picture border; a card bearing the name of the observer; a scene-number indicator; and a meter which photoelectrically monitors the projector lamp output. The single-picture shaft of the recording camera is driven through a clutch which makes one turn when the solenoid tripping device is energized. This picture preserves an accurate, positive record of all the important items of data.

The whole experiment is controlled by the observer from a small portable switchboard, upon which are located switches for starting the projector, regulating the border brightness, darkening or brightening the picture, and actuating the trip that allows the camera to take one picture of the instrument settings.

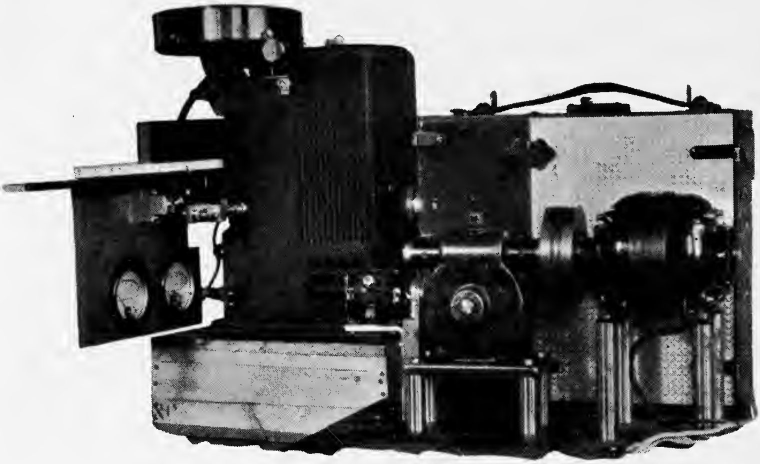

FIG. 2. Projector and recording camera.

Test-scenes have been selected with a great deal of care, although it can not be stated positively that they are entirely satisfactory for the purpose.

The most convincing data would be obtained if a great many actual release prints could be used in the experiment. Such a procedure is temporarily out of the question, not only because the 16-mm. size was used, but because the time required of volunteer observers would be too great if the number of scenes were not limited.

The scenes—six in all—were obtained through the courtesy of one of the large professional studios. Both negatives and 35-mm. prints were supplied, which were certified to be of standard release print quality. Comparison of sensitometric characteristics of the release prints and of our reduction copies of the negative, with data reported elsewhere in this issue of the JOURNAL shows that they are not unusual. Measurements of maximum, minimum, and average projection density of the prints that were used are given in Table I.

TABLE I

Optical Characteristics of Sample Prints

Scene Description	Scene No.	$D_{min.}$	$D_{max.}$	$D_{av.}$	Scene No.	$D_{min.}$	$D_{max.}$	$D_{av.}$
Exterior long-shot (large group of persons in field)	*Ia*	0.65	2.2	1.3				
Exterior long-shot (tilt shot of tower against sky, with gradually disclosed sky area)					*Ib*	0.20	2.2	0.45–0.2
Interior long-shot (orchestra)	*IIa*	0.60	3.0	1.3	*IIb*	0.39	2.9	0.78
Exterior long-shot (children dancing)	*IIIa*	0.36	2.6	1.0	*IIIb*	0.52	2.4	1.20
Interior close-up (radio announcer)	*IVa*	0.55	2.7	1.1	*IVb*	0.36	1.9	0.71
Interior semi-close-up (man in evening dress)	*Va*	0.52	3.2	1.40	*Vb*	0.24	2.4	1.00

This table is composed of two parts, showing the optical characteristics of two sets of prints used, respectively, in two parts of the subsequent observational procedure. The first set of prints, designated by *a*, was made as the result of a trial-and-error attempt to match the quality of the original 35-mm. prints by visual comparison of the screen results as the 35- and 16-mm. scenes were projected side by side. The second set, marked *b*, differs somewhat in quality from the first. With one exception, the same negatives were used for both sets. The *a* scenes were used with the nine observers. The *b* scenes were used with the four observers in the experiments to be described.

OBSERVATION PROCEDURE AND RESULTS

The observation procedure that was adopted consists in first preparing an observer by asking him to read or write upon white paper for ten minutes at a known illumination level. The brightness level chosen for this adaptation period is 5 foot-lamberts, and was based upon a careful survey of lobby brightness in Rochester theaters with a Macbeth illuminometer calibrated to read directly in brightness units. We believe that the conditioning illumination for the evening theatergoer is set principally by lobby brightness, and that a conditioning field approaching this level most nearly imitates practical conditions. It was found, as might have been expected, that the brightness of conspicuous objects in a theater lobby varies over wide limits, but 5 foot-lamberts represents a fair average for the lobbies of the more prominent theaters of this city. We are indebted to the managers of these theaters for their coöperation in this survey.

Subsequently to the conditioning period, the observer is placed in a seat at a distance of 12 feet from the screen. The screen subtends at the eye an angle of 12 degrees, and the illuminated border an angle of about 30 degrees. The screen angle represents about the average viewing condition in theaters, although the actual viewing distance is considerably less. In our opinion, this latter departure from theater conditions is of small importance, since only one-fourth diopter accommodation and convergence is required.

The observer is first asked to familiarize himself with the panel board controls. He varies the screen brightness over a wide range and learns to use the signal button which operates the recording camera. Regular observations are then begun, the five scenes each of thirty to forty seconds duration being projected, with a fixed border illumination, the observer adjusting and recording the screen brightness for each scene to suit his own preference. As the first scene in the repeater magazine again enters the gate, the border brightness is set to a new fixed value and the screen brightness settings are made by the observer as before.

The border brightnesses selected range from zero to 0.8 foot-lambert, the latter figure being agreed upon by all observers as too bright for comfortable observation. It became evident from preliminary observations that small changes in border brightness below one foot-lambert would have no noticeable effect upon the selected value of screen brightness, so only four steps have been used, namely zero, 0.05, 0.20, and 0.80 foot-lambert. We have adopted, for the present, a sequence starting at zero border illumination, rising to maximum, returning by steps to zero, rising again to maximum, and finally re-

TABLE II

Brightness (Foot-Lamberts) Selected by Each of Nine Observers for Five Scenes

Border Brightness	*Ia*	*IIa*	*IIIa*	*IVa*	*Va*	Av.	*Ia*	*IIa*	*IIIa*	*IVa*	*Va*	Av.
	Observer No. 1						***Observer No. 2***					
0.00	25	32	35	34	67	38	67	60	49	41	67	57
0.05	35	34	53	51	46	44	44	35	39	42	47	41
0.25	17	17	17	14	19	17	47	53	67	25	67	52
0.80	34	12	17	22	32	23	34	46	51	42	60	46
Average	28	24	31	30	41	31	48	49	52	38	60	49
	Observer No. 3						***Observer No. 4***					
0.00	24	29	23	16	24	23	26	25	15	18	14	20
0.05	11	12	19	12	25	16	24	26	15	17	16	20
0.25	36	31	35	25	23	30	14	22	11	9	11	14
0.80	14	16	14	9	31	17	19	23	17	9	12	16
Average	21	22	23	16	26	22	21	24	15	13	13	17
	Observer No. 5						***Observer No. 6***					
0.00	49	40	46	37	57	46	35	23	51	24	25	32
0.05	67	34	40	47	39	45	38	17	35	16	25	26
0.25	55	34	26	35	67	43	32	24	36	23	39	31
0.80	42	44	67	51	67	54	36	32	41	34	34	35
Average	53	38	45	43	57	47	35	24	41	24	31	31
	Observer No. 7						***Observer No. 8***					
0.00	34	51	38	34	39	39	44	32	46	36	40	39
0.05	29	36	25	19	38	29	25	22	28	32	35	29
0.25	12	35	35	15	26	25	40	35	34	38	37	37
0.80	45	35	39	19	41	36	38	55	35	40	47	43
Average	30	39	34	22	36	32	37	36	36	37	40	37
	Observer No. 9											
0.00	46	36	46	34	40	41						
0.05	44	35	37	29	41	37						
0.25	67	67	39	49	67	58						
0.80	67	67	45	45	60	57						
Average	56	51	42	39	52	48						

turning by steps to zero. This sequence requires an observer to view each scene thirteen times. The routine takes about forty minutes for each observer and nets a total of thirteen observations for each of the five scenes.

The projector has been operated throughout the experiments at the rate of 24 frames a second. It is equipped with a two-bladed shutter, so that the flicker frequency is 48 cycles per second. This value is higher than the critical frequency for the maximal screen brightness available, so that no flicker is perceptible even when the projector is running at maximal screen brightness and without film in the gate.

Nine observers were used for the first set of prints—those designated by *a* in Table I. Results for each observer are given in Table II. The data are given in foot-lamberts and refer to the center brightness of the screen with the projector running with no film in the gate. Each figure entered for each border brightness and scene-number is, in itself, an average of the several selections made according to the routine described above. In Table III are given the grand averages for the nine observers by scenes and by border brightnesses.

TABLE III

Grand Averages for Nine Observers, by Scenes and by Border Brightnesses

Border Brightness	*Ia*	*IIa*	*IIIa*	*IVa*	*Va*	Averages
0.00						37
0.05						32
0.25						34
0.80						36
Averages	37	34	36	29	40	35

At the conclusion of the first set of observations, the negatives were reprinted in a second attempt to represent the somewhat mythical "standard release print quality." Statistical release print data shown elsewhere in this issue of the JOURNAL were consulted, and the scenes were printed so as to represent, as well as could be done with five scenes, a cross-section of these data. All were developed to a gamma of 2.0, because this is the average value used in release print laboratories. This second set of prints was shown to four additional observers. The average data are given in Table IV.

TABLE IV

Average Brightnesses Selected by Four Observers

Border Brightness	*Ib*	*IIb*	*IIIb*	*IVb*	*Vb*	Average
0.00						29
0.05						30
0.20						30
0.80						28
Averages	21	28	45	24	28	29

There appears to be no correlation between border brightness and the screen brightness selected, over the range of border brightness here used; yet the brightest border used was definitely brighter than that preferred by any observer. The majority of the observers preferred border brightnesses of 0.05 to 0.20 foot-lambert, while none preferred the brightness of 0.80, and only three of the thirteen observers preferred the dark border.

There appears to be only a slight correlation between preferred screen brightness (as measured with projector running empty) and the density of the print, although there is a slight tendency to increase the projector brightness to compensate for a very dark print. This is

TABLE V

Repeatability of Observations by One Observer (No. 4) on Three Separate Days

Scene Border	*Ia*	*IIa*	*IIIa*	*IVa*	*Va*	Average
0.00	21	20	14	13	14	17
0.05	24	26	15	17	16	20
0.25	14	22	11	9	11	14
0.80	19	23	17	9	12	16
Average						17
0.00	14	17	13	10	15	18
0.05	14	15	11	8	11	12
0.25	14	12	11	7	8	11
Average						14
0.00	14	15	17	14	14	15
0.05	17	17	22	17	15	17
0.20	15	16	20	16	15	16
0.80	20	23	22	17	15	17
Average						16

particularly marked in the case of scene *3* of the second set, this scene showing a particularly high minimum density and low total transmission.

In order to determine whether an observer's preference was consistent from one day to another, observer No. *4* of the first set was asked to record on three different days. His results for three days are shown in Table V. It will be noted that very consistent preference was shown for a definite screen brightness, although it is impossible from the observing position to form any idea at all of the absolute brightness level at which the projector happens to be set, other than by visual memory. Since visual memory of brightness is known to be very faulty even over a period of a few minutes, it seems unlikely that any possible prejudice could have entered into these results.

CONCLUSIONS

The average screen brightnesses selected by thirteen observers varied from a minimum of 17 to a maximum of 49 foot-lamberts, a grand average of 32 foot-lamberts. Border brightness has no influence upon selected screen brightness up to a border brightness of 0.8 foot-lambert, a value brighter than preferred by any observer. An observer desiring a screen brightness much lower than the average was consistent in his selection on three days with a maximal spacing ten days apart. It has not been determined whether all observers would be equally consistent. The nature of the scene and the print density has some effect upon the selected screen brightness, but this effect is less than would be expected either from a consideration of the nature of the scene or of print density data.

The observations reported are necessarily preliminary, and many more observers and a greater variety of prints must be used before any final conclusion can be drawn. It is interesting to note, however, that the spread of average preferred screen brightnesses among thirteen observers is less than three to one, and that the average selected brightness of the highlights of the projection screen as viewed (with film in the projector) is not far from the figure of 10 foot-lamberts previously cited as the minimum acceptable for close work at a desk. It must be remembered that a brightness of 10 foot-lamberts, of the highlights of the scene as viewed, corresponds to about 30 foot-lamberts produced by the projector running with an empty gate.

A plot of the just-perceptible brightness difference ΔB, expressed as a fraction $\Delta B/B$ (the Weber-Fechner fraction), is shown in Fig. 3

for a natural pupil with $\log_{10} B$ (in foot-lamberts) as abscissa. This has been determined for a 3-degree field. It is of interest to note that at the selected screen brightness only the light portions of the projected scene are at a level lying within the flat portion of the curve, or region of maximal brightness discrimination. For a print whose density range is from 0.3 to 2.0, for example, with an empty projector brightness of 30 foot-lamberts, the scene brightness range will lie between 15.0 and 0.3 foot-lamberts. These limits are shown by crosses on the curve.

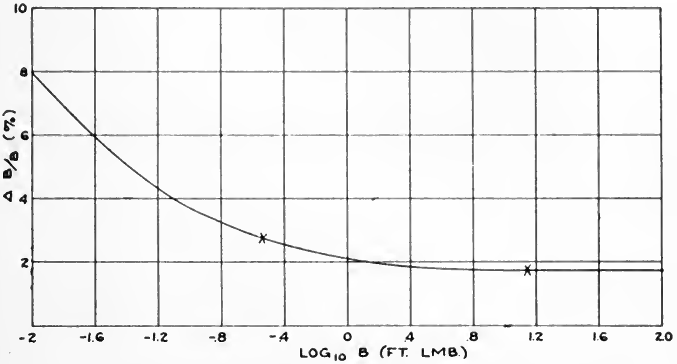

FIG. 3. Weber-Fechner fraction as a function of brightness.

It is not certain what factors are involved in the selection of a given brightness level by an observer, but it seems probable that ability to discriminate between brightness differences is only one of several factors, although it may be among the most important. Visual acuity may be another, and perhaps, other factors which we have not touched upon.

(For discussion, see p. 518)

JOINT DISCUSSION OF

SCREEN BRIGHTNESS AND THE VISUAL FUNCTIONS*

by

E. M. LOWRY

and

AN EXPERIMENTAL INVESTIGATION OF PROJECTION SCREEN BRIGHTNESS**

by

B. O'BRIEN AND C. M. TUTTLE

Mr. Tuttle:[†] Mr. Lowry, can you tell us, from the acuity data you have gathered, what is the minimal brightness required to see upon the screen all the detail that an optically "good" motion picture image contains? From our experience it appears that a motion picture seems to lack definition if, for some reason, either optical or photographic, the resolution of the positive image falls below 500 lines per inch. Since this value is based upon the judgment of a critical observer who would pass upon the definition by close inspection of the screen, it would seem fair to ask the question of an observer seated rather close to the screen. Assume, then, that a member of the audience sits 30 feet from the screen, and that the picture magnification is 250 diameters. How bright should the screen be to see the image of the detail resolved in the release print when the contrast is of the order of 100 to 1?

Mr. Lowry:[†] It should first be emphasized that the data available are for the most part those applying to threshold conditions and for rigidly controlled surroundings, the general case being a black test-object against a uniformly illuminated white background. For the specified requirement of a resolving power in the film of 500 lines per inch and a screen magnification of 250, the linear dimension of the smallest detail in the projected picture would be approximately one-half inch. This corresponds to a visual angle of five minutes subtended at the eye of an observer 30 feet from the screen. A visual angle of 5 minutes requires a visual acuity of only 0.2, and for the normal eye the necessary field brightness is something less than 0.1 foot-lambert.

Mr. Tuttle:[†] What brightness would be necessary if the viewing distance were increased to 60 feet?

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* See p. 490.

** See p. 505.

[†] Communicated.

MR. LOWRY:† Increasing the viewing distance to 60 feet would reduce the visual angle to 2.5 minutes, or a visual acuity of 0.4, which under the same conditions of contrast would require a screen brightness not greater than 0.1 foot-lambert. Data for a wide range of background brightness are shown in Fig. 1.

MR. SCHLANGER: Mr. Lowry, were the recent tests made by Ellis, Freeman, and Luckiesh on stimulus distance taken into consideration?

MR. LOWRY: Those data were not included in the work reported in this paper. I believe that Luckiesh found that visual acuity increases with distance.

MR. SCHLANGER: That information is important because the viewing distances in the theater vary sufficiently to bring that factor into consideration.

Referring to O'Brien and Tuttle's paper, I assume that the illuminated screen border is to serve as an area of transition between the screen and the audience, in addition to its having some bearing upon the screen brightness problem. Will the intensity of this illuminated border be uniform all around the screen? The brightness of the edges of the screen image varies with the nature of the photographed scene, and the contrast between an edge of the screen and the screen border may vary to a disadvantage.

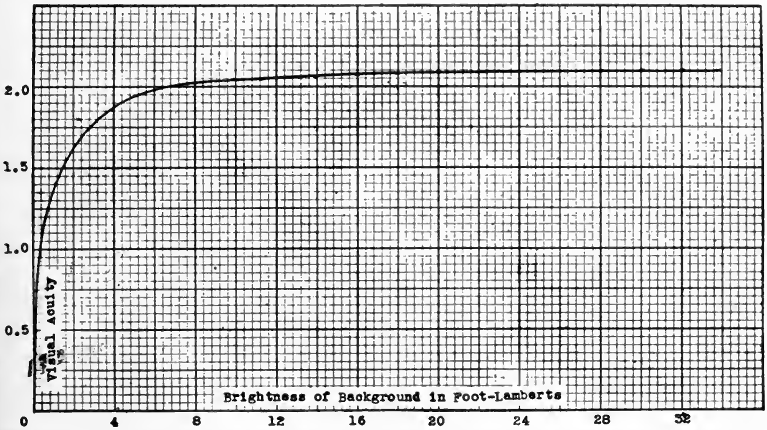

FIG. 1. Relation between visual acuity and brightness of background, according to Luckiesh.

MR. TUTTLE: We are using a uniform illumination of the border.

MR. SCHLANGER: A very dark area of the screen image adjoining an illuminated border would be as unsatisfactory as a light area of the screen adjoining a dead-black border. Strong contrast at the edges of the screen makes the viewer picture-frame conscious.

Peripheral screen images would automatically take care of the problem, since the image area would extend beyond the limits of the screen into the border area. The brightness of the peripheral area would vary constantly with the scenes that are imaged. There would be a more natural transition between the screen and the audience, and at the same time there would automatically be provided an area of suitable brightness about the screen without having to create a special artificial border.

In regard to determining the correct size and brightness of the screen, we must take into consideration contrast, viewing distance, stimulus distance, visual acuity, and so forth. One of the difficult problems is that of determining the proper viewing distance. For example, a certain brightness may be satisfactory for extreme viewing distances, but may be too low for the spectators near the screen.

To establish a brightness level that would be most efficient and best for the greatest number of seats in the theater, it would first be necessary to determine the optimal viewing distance in relation to the width of the screen or the screen image size. If we could determine that relation, we should have a definite point from which to start in determining the proper brightness.

It would, of course, be necessary to determine the visual acuity desirable; and in order to determine that, it would first be necessary to establish the amount of detail in the screen image that should be discernible by the viewer. That is an open point and could probably be answered best by the directors who make the pictures. The final visual requirements of the viewer must not be forgotten: the viewer must enjoy the full effect intended by the director of the production. We should seek from directors and cinematographers their ideas as to what detail must be discernible in, let us say, close-ups, medium shots, and long shots.

MR. CARVER: Do I understand Mr. Tuttle correctly, that in his tests the observer began with the minimum level; and sometimes also with the higher levels of brightness? If in both directions, was there a difference?

MR. TUTTLE: The observer can make the wedge go in either direction. He starts with it either too high or too low, and adjusts it to suit himself.

Mr. Schlanger has brought up a very interesting point. The question of the variable brightness of the peripheral area is one that we hope our data will answer. Anything we say now may be jumping at conclusions, but it is my impression, after having gone through this experiment several times, that the peripheral brightness is not very critical; but that a border of given and constant brightness changes the whole aspect of the picture. My feeling when the border illumination is turned on is that a very distinct improvement has taken place. However, the brightness of the border apparently does not affect the brightness of the picture provided that that brightness is high enough.

MR. SCHLANGER: I believe that Helmholtz and others regarded the peripheral area as one of transition from the light in front of the eyes to the black behind the head. The area is variable; sometimes a black might occur in the left peripheral area while in the right area a greater amount of light might be seen, subject to the nature of the objects in the peripheral area. That again brings up the point that we must be careful not to have a dark peripheral image contiguous to an illuminated area of the screen border.

Would it not be better to use in these tests a half-scale or other size model, or some arrangement that would permit making an "auditorium test," which would take into consideration the screen, the areas contiguous to the screen, and the other areas of the auditorium that come within the field of view of the spectator? While we are determining the optimal screen brightness we can at the same time accomplish something else—determine the auditorium illumination that will best complement the screen brightness. It would be better if more tests could be made, possibly in combination with the smaller-scale tests.

MR. JONES: The program of the Committee is a long one, and can not be accomplished in a few months. I believe the Committee has taken the point of view that it is best to begin with simple things first. The question of screen environment has been placed upon the program, and measurements in theatrical surroundings have been planned. The Committee will gradually build its work up to the more complicated parts of the problem. We must try to be a little patient.

MR. JOY: Will Mr. Tuttle give us more information upon the methods used in this work to determine the correct screen brightness? What is the distance of the observer from the screen, and what is the size of the screen? Do you intend to use test-films in which the major portion of the picture is dark and other test-films in which the major portion is light? Have you standardized the distribution of light upon the screen—that is, the ratio of the light at the center to the light at the sides or corners of the screen without film in the machine? Do you intend to determine the effect of varying this distribution?

MR. TUTTLE: We have attempted to select pictures that are a cross-section of release print quality, both from the point of view of transmission and brightness distribution. We have done this on the basis of a study reported in another paper in this symposium, a study of release print density. Of course, we are limited as to the number of subjects we can use. Actually, we are using only five scenes at present: two exteriors, having quite different distributions of subject matter, light and dark; and three interiors, one of which is a close-up, one a semi-close-up, and the other a long shot.

The choice of subject, we realize, will always be open to criticism. Perhaps we are not using the proper ones; but upon the basis of statistical data presented in another paper, we have chosen the subjects that seemed best to represent actual theater prints.

We are planning to vary the distance of the observer from the screen, thinking that the angle subtended by the screen at the observer's eye may be an influencing factor in the choice of brightness. We are doing the first experiment at a distance of twelve feet from a three-foot screen; and as to the distribution, the screen illumination is very uniform, in fact, it falls off at the edges only by the theoretical unavoidable amount.

A REVIEW OF PROJECTOR AND SCREEN CHARACTERISTICS AND THEIR EFFECTS UPON SCREEN BRIGHTNESS*

A. A. COOK**

Summary.—*Two fundamental factors determine the light output of the motion picture projector: (1) source brightness and (2) the effective aperture of the projection optical system. When these are known accurately, the number of lumens available for screen illumination can be computed, after making allowances for losses that occur in the collective element, the shutter, and the objective lens. The method of computation is described, and results are given for typical projectors. It should be noted, however, that adjustments are made in the practical operation of projectors that can produce wide variations in the two fundamental factors. Therefore, the conditions of operation must be precisely known in order to apply the results to any particular installation.*

Screen brightness can be derived directly from the lumen output when the screen factors—area, reflectivity, and directional properties—are considered.

The first portion of this study of available screen brightness will be devoted to the motion picture projector; and particularly, to the optical parts of the projector. These optical elements vary considerably in size, shape, and position in the various types of machines used in theaters. But all of them have certain features in common. There is always a light-source, a collective element to form an image of the source at or near the film gate, and a projection lens to image the film upon the screen. All but one of these five parts of the optical system are subject to wide variation in practice, and that one is the aperture of the film gate. The useful light that is transmitted to the screen must pass through that opening. It is a convenient point, therefore, at which to evaluate the total light output of the projector.

A suitable method of computing illumination in projectors was described in the JOURNAL several years ago.[1] It will be appropriate to review it briefly, using as an example the schematic optical system shown in Fig. 1. The drawing shows the essential elements of a projection system: light-source, collective element, film gate, and

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** Bausch & Lomb Optical Co., Rochester, N. Y.

projection lens. The collective element in this arrangement happens to be a condenser, but the argument applies equally well when a reflector is used. It is assumed for the moment that this optical system is an ideal one. Such a system may be defined as follows: The source is perfectly diffusing; the image of the source upon the film gate is large enough to cover the opening in the gate; there are no defects in image formation; the collective and projection elements can transmit light through the entire angle 2θ to all points upon the film. Under these conditions the light-intensity per unit area, E, at the film gate is determined by the equation

$$E = \pi B \sin^2 \theta \tag{1}$$

where B is the source brightness and θ is the half-angle through which light is received at the film gate from the collective element. If losses of reflection and absorption are neglected, the equation is mathematically exact for the center point of the film. In this ideal system the intensity at the gate is practically uniform, and the total illumination passing through the film aperture is equal to E, the intensity per unit area, multiplied by the area of standard aperture:

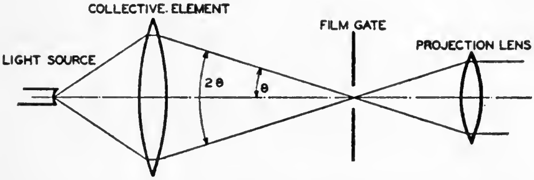

FIG. 1. Schematic diagram of projection optical system.

$$I = 319.35\, \pi B \sin^2 \theta \tag{2}$$

Since in this equation the aperture area is in sq. mm., the source brightness, B, can be stated in candles per sq. mm., and the numerical value of the illumination in lumens.

Suppose that this ideal projector is now arranged to image the film aperture upon a distant screen, and is at right angles to the screen and properly centered. Neglecting reflection and absorption losses again, the screen illumination will, in general, not be uniform. There will always be less light at the margin of the screen than at the center, and the loss increases progressively from the center to the margin.

There are two reasons for this condition. The margins of the screen are farther from the lens than the center; and the lens points directly at the center of the screen whereas to any marginal point it presents its surface at an angle. This loss in marginal illumination is not large in the case of an ideal optical system. With a 3-inch focus projection lens, for example, it amounts to $5^1/_2$ per cent at the extreme corner of the screen. It will be considered again later, together with the losses that occur under practical conditions.

With this exception, the ideal projector will deliver to the screen an amount of light that can be calculated from equation *2*. The important point is that no projector with standard aperture can be made to furnish more light than I, when it uses a light-source of brightness B and an optical system whose relative aperture corresponds to the angle θ. The equation sets a limit that might be equalled, perhaps, but never exceeded. Furthermore, by combining with equation *2* an estimate of the many light losses that can not be avoided in practice, one can set up a standard by which the efficiency of any practical projector can be measured.

TABLE I

Relative Illumination of Projection Systems

f/number	θ	$\pi \sin^2 \theta$
2.0	14° 2′	0.1848
2.2	12° 48′	0.1543
2.4	11° 46′	0.1307
2.6	10° 53′	0.1121
2.8	10° 7′	0.0971
3.0	9° 28′	0.0849
3.2	8° 53′	0.0749
3.4	8° 21′	0.0665

It is evident that the angle θ is a measure of the illuminating power of the optical unit, but it is not the familiar one used in expressing this value for projection optics. It is customary to use the *f*/system, or relative aperture, to indicate the speed of projection lenses. In Table I are listed the values of θ for *f*/numbers from 2.0 to 3.4, and a third column has been added to give the factor $\pi \sin^2 \theta$ for each. The last column is the important one, for it expresses the illuminating power of the optical system, the ratio between source brightness and intensity, and shows how this factor varies with a change in relative aperture.

All this discussion has been concerned with an ideal projection system, and no account has been taken of the losses of light that occur in any practical projector. These loss factors must now be estimated in order to establish a basis for the light yield of any actual optical system. In making the estimate some regular procedure is advisable, so we shall start at the light-source and follow the path of the light through the projector.

The brightest sources available for projection are arc lamps. They have been measured by methods described in the literature, and many reports of their performance have been published.[2] From these data Fig. 2 has been prepared, to show the intrinsic brilliancy of typical arc lamps as used in practice. The range is from 165 candles per sq. mm. for the low-intensity arc to 750 for modern high-intensity carbons. It should be noted, first, that the arcs can be operated at currents higher than the manufacturers' ratings, with a resulting increase in brightness; and second, that the brightness level indicated in Fig. 2 is attained only at the crater of the arc and is an average figure for the area of the crater. The outer part of this area is not generally as bright as the center, which fact is one cause of the lower illumination at the margins of the screen.

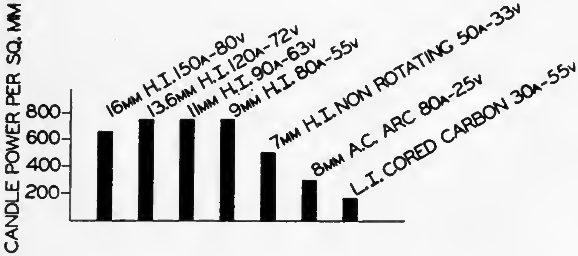

FIG. 2. Intrinsic brilliancy of typical arc lamps as used in practice.

In the outline of an ideal optical system the source was assumed to be perfectly diffusing, which meant that it appeared equally bright from every direction of observation. The arc crater used as a source in practical projectors does meet this specification approximately, within the angle included by the collective element.[3] The only exception that need be noted occurs when the negative carbon or the carbon holders cut off part of the useful light that would otherwise pass through the film gate.

In the case of condenser lamps this is not a factor. In good designs there is no shadowing by the mechanism or the negative carbon. There are losses in condensers due to reflection and absorption, which vary with the number of elements and the thickness and quality of the glass. The condensers now used are usually of the two-element type, the losses ranging from 17 to 25 per cent; 20 per cent is a good average for modern practice. It will be convenient to express all these factors as transmission, and call this one a condenser factor of 80 per cent.

With reflectors the light lost through absorption and reflection at the surfaces is less, but there are other factors that reduce the efficiency. The negative carbon obscures part of the reflecting surface, and the glass must be pierced to provide space for feeding the carbon. The positive carbon assembly also interferes to some extent. These, factors in addition to a small allowance for loss at the silvered surface, make the total loss in a practical reflector lamp about equal to that in the condenser type. There is the usual variation in different designs. Eighty per cent will be taken as the transmission factor of the collective system.

The light now proceeds to the film gate, losing on the way a full half of its volume due to the mechanical cut-off of the shutter. The shutter factor is 50 per cent. At the plane of the film no losses will be assumed: this loss involves the density of the release print, and will not be considered here. All the data to be presented are computed upon the basis of a complete projector with shutter operating, but without film in the machine.

Next in order is the projection lens. Many types of objectives are used in theaters. All have loss-factors due to reflection at the free surfaces and to absorption in the glass itself. The transmission of commercial lenses varies from 63 to 80 per cent, depending principally upon the number of free surfaces in the glass elements.[4] Most of the lenses in use are of the Petzval type, in which the transmission averages 75 per cent.

There is another cause of loss, however, to be considered in connection with projection lenses. It was mentioned earlier that even in an ideal system the illumination at the edges of the screen is inferior to that at the central region. This fact is a result of the space relations involved in projection, and is unavoidable. Practical lenses are so constructed that they make the condition worse, as illustrated in Fig. 3. Due to the length of the projection lens, the full area of its front surface can not be filled with light for the margin of the picture area. These two factors operate together to reduce the marginal illumination considerably, and the effect grows worse as the focal length of the lens decreases. In Fig. 4 are shown the computed values of these factors for typical $f/2.5$ projection lenses of 3- to 6-inch focal length. The value given for each focal length is an average of the calculated transmission for thirteen different points evenly spaced over the picture area, and is a reasonable estimate of the loss in screen lumens due to the two conditions just described. The factor is 56 per cent for a 3-inch lens, and 86 per cent for a 6-inch lens. Eighty per cent is a good average for the purpose of this estimate.

The results of combining all these data are given in Fig. 5. The number of available screen lumens has been computed according to equation *2*, and then corrected for all the factors that might be called unavoidable losses. The final value of all these is 0.80 × 0.50 × 0.75 × 0.80, or an efficiency of 24 per cent for the entire optical unit.

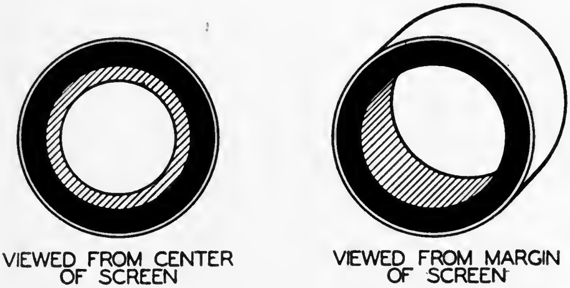

FIG. 3. In practical lenses the full area of the front surface is not filled with light for the margins of the screen picture area.

This diagram is useful in many ways. In respect to light-sources, the bottom curve represents the limit of illumination to be expected from lamps using low-intensity carbon arcs. The upper curve gives the same information for large high-intensity carbons. The middle curve is the brightness level of the 7-mm. high-intensity non-rotating carbon. The range is from 2350 to 10,600 lumens with optical systems of $f/2.0$; and from 1650 to 7500 lumens at an aperture of $f/2.4$. The result of a change in relative aperture can be derived in a similar manner. The largest aperture that need be considered at present is $f/2.0$, for reasons that will appear shortly.

These results indicate the number of lumens that a well designed projector should deliver to the screen. It is not to be expected, however, that even the best of modern commercial projectors will attain this level. It was pointed out in the discussion of light-sources that the outer edge of the arc crater is not as bright as the center in high-intensity carbons. This causes a loss of light at the margin of the screen; the projection lens has the same effect even when it is *completely* filled with light. Moreover, this last condition is not fulfilled for the corners of the screen by the condensers and reflectors now in use, as is well known and has been discussed previously.[5] There is little to be gained by increasing the aperture of the projection lens beyond $f/2.0$ at the present time. An $f/2.0$ optical system can not be assembled simply by taking out an old $f/2.4$ projection lens and putting in a new one of $f/2.0$. To get a real increase in relative aperture the collective element must also be large enough to fill the larger angle of the new lens.[6]

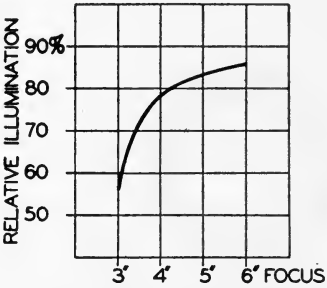

FIG. 4. Reduction of marginal illumination with focal length of lens, due to effect illustrated in Fig. 3.

The practical result of these three deficiencies in marginal screen light is this: When the system is adjusted for maximum light output, the corners of the picture are too dark; to correct this the arc is re-focused and the source image moved out in front of the film gate until the distribution of light between the margin and the center is deemed satisfactory. At this adjustment the optical system no longer gives its maximum output.

It is not possible to present here the actual measured yield of any type of commercial machine as installed in the theater. No sufficient information has been published. Measurements made under laboratory conditions indicate that the maximum output to be expected from commercial projection systems is in the neighborhood of 5000 lumens with higher intensity. There is no essential difference between condenser and reflector lamps in this respect. Low-intensity reflector arcs furnish about 1250 lumens under these conditions, and lamps using the 7-mm. non-rotating carbons, 4500 lumens.

It appears, then, that available projection machines can provide 5000 lumens of screen light. The exact figure is of little importance, in view of published reports of differences as great as 100 per cent between two projectors installed in the same theater.[7] The output varies, probably, all the way from 700 lumens to 4500, in what may be called the entire scale of arc illumination in theaters.

In the process of applying this lumen output to the screen area and estimating the resulting screen brightness there are, fortunately, no factors that need to be estimated. The 1931 report of the Projection Screens Committee[8] gives complete data. Apparent screen brightness for a given amount of illumination varies with the character and reflectivity of the screen material, the projection angle, the position of the observer, and the amount of stray light that reaches the observer's eyes from other objects within his angle of vision. The last two of these factors are outside the scope of this paper.

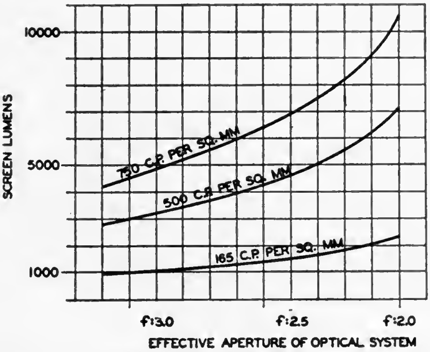

FIG. 5. Available screen lumens, after allowing for losses.

Two kinds of screens will be considered here. The diffusing type is used in theaters when a wide angle of seating area is to be covered, and has, in general, a reflection factor of 80 per cent when the projection angle is 15 degrees. In long, narrow houses, a directional type of screen can be used, which has the property of building up the apparent brightness over an angle of about 20 degrees. Direct reflection from finely divided specular material upon the screen surface is responsible for this result, and the reflection factor of such screens, in terms of apparent brightness, is 160 per cent, according to the 1931 Report.[8] This value applies also to a projection angle of 15 degrees, which is regarded as an average in commercial practice.

There is also a loss of 5 to 8 per cent in reflecting area to be combined with these factors, due to the perforations for sound transmission. Accordingly, the values 75 and 150 per cent have been used in compiling the data for the curves of Fig. 6. Screen width is plotted along the horizontal axis and apparent brightness in foot-lamberts along the vertical axis. The scale at the left applies to a diffusing screen; on the right, to a screen of the directional type. Curves have been drawn to show the average apparent brightness of the screen for projector outputs of 5000, 3000, and 1000 lumens. These curves apply when the projection angle is 15 degrees. When the angle increases to 30 degrees, the loss of brightness occasioned thereby is about 7 per cent for the diffusing screen, and 50 per cent for the directional screen. It is evident that directional screens are of little value when the projection angle exceeds 20 degrees.

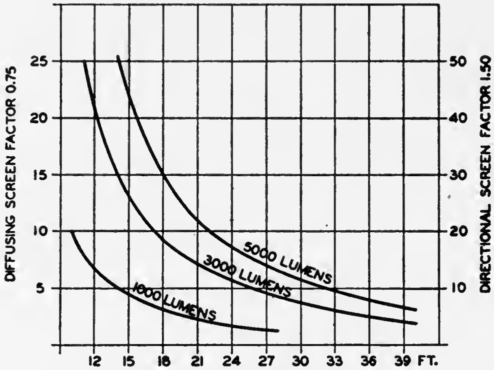

Fig. 6. Screen brightness in foot-lamberts for diffusing and directional screens. Screen width is the dimension specified.

Source brightness and effective aperture are the fundamental factors that determine the lumen output of any projection optical system. Variations in current or carbon spacing causes large changes in the brightness of the arc crater. Small differences in the position of the source in relation to the collective element can rapidly reduce the effective aperture. These variable quantities must be carefully controlled in order to get consistent results from the optical system. It is often possible to achieve a large increase in brightness at the center of the screen and an increase in total lumens by sacrificing at the margins. Any standard that may be established should certainly include a definition of what constitutes uniform illumination and a specification of the points at which it is to be measured.

REFERENCES

[1] HARDY, A. C.: "The Optics of Motion Picture Projectors," *J. Soc. Mot. Pict. Eng.*, **XIV** (March, 1930), No. 3, p. 309.

[2] JOY, D. B., AND DOWNES, A. C.: "Characteristics of High-Intensity Arcs," *J. Soc. Mot. Pict. Eng.*, **XIV** (March, 1930), No. 3, p. 291.

[3] JOY, D. B., AND DOWNES, A. C.: "Direct-Current High-Intensity Arcs with Non-Rotating Positive Carbons," *J. Soc. Mot. Pict. Eng.*, **XXII** (Jan., 1934), No. 1, p. 42.

[4] HARDY, A. C.: "The Distribution of Light in Optical Systems," *J. Franklin Inst.*, **208** (Dec., 1929), No. 6, p. 779.

[5] KELLNER, H.: "Absorption and Reflection Losses in Motion Picture Objectives," *Trans. Soc. Mot. Pict. Eng.*, **IV** (1920), No. 11, p. 74.

[6] RAYTON, W. B.: "The Effect of Aperture Lenses on Illumination," *J. Soc. Mot. Pict. Eng.*, **XXIII** (Dec., 1934), No. 6, p. 309.

[7] WILCOX, H. M., AND CONROW, L. W.: "Some Technical Aspects of Theater Operation," *J. Soc. Mot. Pict. Eng.*, **XXIII** (Dec., 1934), No. 6, p. 340.

[8] Report of the Projection Screens Committee, *J. Soc. Mot. Pict. Eng.*, **XVII** (Sept., 1931), No. 3, p. 437.

(*For discussion, see p. 543*)

AN ANALYSIS OF THEATER AND SCREEN ILLUMINATION DATA*

S. K. WOLF**

Summary.—*During the past twenty years much information on theater and screen illumination has been accumulated. The significance and reliability of these data are discussed in the light of known physical factors influencing proper illumination. As a first approximation to a standard, it is suggested that the data indicate a value of 8 to 12 foot-candles as representing satisfactory illumination. Variation of required illumination with screen size is analyzed, and a solution of the problem is suggested. The brightness of screen surroundings also is discussed. It is concluded that improvement in projection may be made by stricter application of existing information but that further investigations are desirable.*

One of the earliest topics considered by the Society was the illumination of motion picture theaters and screens. Since the formation of the Society, again and again the engineers of the industry have turned their attention to the problem, but as yet no definite answers have been forthcoming. However, practical answers have been furnished and some data have been accumulated. The data are not precise, and uncertainty exists; but at least tolerable conditions have been attained. This seems always the case whenever engineering science comes into contact with physiological and psychological phenomena: exact standardization and great accuracy are impossible because of the wide latitude of conditions to which human mechanisms can adapt themselves. This paper will deal with some of the physical factors involved, and thence proceed to a discussion of the data accumulated thereupon in the past two decades. A consideration of physical factors is necessary for an understanding of the theoretical requirements for illumination and the nature of the compromises that have been made.

PHYSICAL FACTORS

Motion pictures projected upon a screen illustrate a wide range of conditions. Brilliant daylight scenes are depicted along with others

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** Electrical Research Products, Inc., New York, N. Y.

supposedly representing pitch blackness and all the variations intervening between the two extremes. In technical terms this means brightness variations ranging from about 10,000 foot-lamberts to less than 0.0001 foot-lambert, for reflected light. The ratio is about 100,000,000 to 1. When we contrast such figures to those available in the theater we realize the severe limitations governing motion picture equipment. A corollary to this is the importance of taking advantage of human adaptability in order to achieve a satisfactory illusion in the theater. Because of various physical limitations, the maximum of screen brightness in the theater is usually less than 15 foot-lamberts, with a minimum of more than 0.15 foot-lambert, a ratio of less than 100 to 1. In the theater, then, we are limited to a comparatively small range, situated approximately at the middle of the natural scale of reflected light values. A saving factor in this connection is that under any one condition of illumination, the contrasts involved in most scenes more nearly approach the range available upon the screen. Another point is that the brightness values characteristic of projection approximate those regarded as normal for interiors. Greater values are generally impracticable with the magnification necessary in projection and the limitations imposed upon light-sources.

Another factor materially changes the complexion of the situation. In the theater we wish to portray life-like scenes, not so much in actuality as creative of a satisfactory illusion of reality. We have a story to tell, and a stage upon which to tell it. The stage is the center of interest; the immediate surroundings are of no concern. We, therefore, blot them out by darkening the theater, not only for motion pictures but in the legitimate theater as well. Concentration of attention upon the stage is thereby facilitated, since from the stage emanate the only visible signs of activity. It is apparent, therefore, that the theater must be kept relatively dark. If, under the circumstances, we attempted to project high values of illumination upon the screen such as are encountered out of doors, a host of psychological and physiological factors would come into play. High illumination would be uncomfortable in contrast with dark surroundings. Rapid sequence of scenes, involving great changes of light values, would strain ocular power of adaptation. The contrast of images projected upon the screen is limited by "flare" of the objective lens. In this connection, it should also be observed that it is deemed good practice to provide ambient light in order to permit the patrons to find their seats, to avoid glare, *etc.*, and that thus some light will be reflected back upon the screen and the contrasts reduced. The result of this combination of factors is that illumination of the screen has an upper, a lower, and variation limits determined by physiological requirements. Similar limits are imposed also by projector and film capabilities. The function of engineering is to make the physical possibilities at least great enough to take advantage of the full range permitted by the physiological factors. The determination of such requirements should be the task of physiologists and psychologists, but engineers have been able to establish tentative relations which experience has indicated as satisfactory if not optimal.

THEATER ILLUMINATION

We have seen that theaters should be maintained dark in order to promote concentration. In some countries, for example, in Germany, it is customary to provide no illumination other than that reflected from the screen.[1] In other countries, sufficient ambient light is provided to permit theatergoers to find their seats and to read their programs with moderate ease. In the United States programs in motion picture theaters are uncommon, but it still appears desirable to make allowance for both conditions, for possible emergencies, and also to relieve the effect of the glare experienced when passing from the bright exterior to the dim interior of the theater. Upon the basis of general principles governing illumination practice, it seems undesirable that all the light in the auditorium be due only to reflection from the screen.

Practice governing ambient theater illumination has become fairly well stabilized. The light-sources should be low-level, and not directly visible. Indirect illumination is much to be preferred, in order to avoid glare in the auditorium. The light-sources should be so arranged that as little stray light as possible reaches the screen. Otherwise, the contrast of the screen image may be materially reduced. For that reason, as well as to reduce eye-strain in transition from exterior to interior, it has been recommended that somewhat greater general illumination be provided at the rear of the theater than at the front, which would seem a reasonable procedure in view of the fact that the intensity of the reflected light is greater near the screen.

In 1920, Jones[2] recommended that general illumination of the order of 0.1 foot-candle be provided at the front, with gradually increasing amounts toward the rear, up to a value of 0.2 foot-candle. These figures apply to a light striking a horizontal plane. He found that under such conditions the picture contrast was not materially reduced, provided that the requirements outlined above have not been violated; in fact, the eye became more sensitive to small brightness differences in the picture. Jones further recommended that no visible area (outside the projected picture) has a brightness in excess of about 2.8 foot-lamberts. In 1931, the Theater Lighting Committee[3] found that intensities of the order of 0.1 foot-candle were satisfactory for permitting patrons to find their seats easily after their eyes had gradually accommodated themselves to the surroundings. This matter was considered also by the Japanese Secretariat Committee on Cinema Lighting, of the International Congress on Illumination. In their report of September, 1931, the Committee advocated[1] the provision of sufficient light for reading 8-point type, the recommendation, based upon tests with observers having normal vision, being 0.18 foot-candle. The report stated further that this value did not degrade the picture contrasts when the screen illumination was equal to or greater than 9.3 foot-candles (without shutter). The data from these sources mentioned above check quite well. The slight discrepancies may be reconciled by adopting Jones's recommendations as a satisfactory compromise for general illumination in theaters.

SCREEN ILLUMINATION

Turning our attention to the screen illumination, we note that screen reflectivity is a factor inextricably associated with illumination. The factor in which we are interested is not so much the quantity of light incident upon the screen as the quantity being returned to the audience. We should, therefore, concentrate upon screen brightness as the primary factor, since it includes both illumination and reflectivity. That has not always been done. Another item not to be overlooked is the intermittency of motion picture projection. The screen is alternately fully illuminated and darkened. Our eyes do not follow the variations, but tend to integrate them. The resulting perceived brightness is approximately, at least, the time-average of the instantaneous brightnesses, and is accordingly proportional to the shutter opening, which is normally about 50 per cent. To avoid confusion, therefore, measurements should be made with the shutter running. Unfortunately, that has not always been done, and as a result some uncertainty is present in existing data. Assuming this precaution taken, measurements then indicate brightness without film in the projector. The brightness of a screen with film in the projector obviously depends upon the density of the film. Even unexposed film, however, appreciably reduces the illumination falling upon the screen. Hence, measurements without film serve only as guides. Judgments as to acceptable initial screen brightness must be made for a particular screen illumination and a particular film. However, film processing has become more nearly uniform, and in the theater it is not customary to make allowance for variations in the average density of black-and-white release prints. For colored prints, it is believed that somewhat more light might be used, although projector limitations generally render that impracticable.

Before examining the available data upon screen brightness, an interesting side issue might be pertinent. For offices, schools, libraries, and other interiors, illuminating engineers recommend illuminations of 8 to 12 foot-candles, these values being satisfactory except when very close work is involved. Observation of motion pictures is not generally in the category of close, exacting work, and casually we might assume that 8 to 12 foot-candles projected upon a good diffusing screen would lead to satisfactory viewing conditions. (Possible exceptions would be films in which detail was important.) The semi-darkened environment of the screen alters the situation somewhat and introduces an unknown element. These values should, nevertheless, be borne in mind for later reference.

The data accumulated in the past show a gradual rise, with the passing of time, in the illumination regarded as satisfactory. However, they represent measurements made under various conditions, and are not strictly comparable; and, furthermore, differing reasons, or no reasons at all, were given for arriving at the various recommendations.

In 1917, Dennington[4] stated that an intensity of 3 foot-candles projected by an incandescent filament source was as satisfactory as an intensity of 4.8 foot-candles projected unsteadily by an arc source, the shutter in both cases being stationary and no film in the machine. With a diffusing screen, these values would at present be considered low, but with a specular screen would give rise to relatively high brightness values over a limited viewing angle. Also about this time, Burrows and Cardwell[5] conducted a demonstration before the Society illuminating a diffusing screen to intensities of 1, 10, and 25 foot-candles, without film or shutter. The consensus was that the first of these values was inadequate, the second not excessive, and the third so glaring as to cause loss of distinction in picture projection.

In 1918, Kunzmann[6] published a curve showing required candlepower *vs.* screen area. The smaller screens were demonstrated as needing more light than the large ones. For example, an intensity of 10.6 foot-candles was recommended for screens 50 sq. ft. in area, and 8 foot-candles for an area of 200 sq. ft. These values are presumably without film or shutter. The question of variation with size will be discussed later.

In 1920, Jones[2] found that about 14 foot-lamberts was the average screen brightness for several Rochester theaters, apparently without film but with the projector running. Jones stated that these values were higher than those obtained in normal practice. No comment was made as to the acceptability of this value of brightness.

The next reference in the records of the Society is the report of the Theater Lighting Committee of 1928.[7] In a series of tests the screen illuminations varied from 5 to 14 foot-candles, without film or shutter. In 1930, the Committee reported[8] that a screen brightness of about 22 foot-lamberts would be distinctly uncomfortable against a dark background from a distance of 24 feet. At a distance of 72 feet, discomfort would be almost imperceptible. This report mentioned a recommendation by the Japanese National Committee on Cinema Lighting to the International Commission on Illumination, specifying an average light intensity of 2.3 foot-candles upon the screen, film and shutter conditions not mentioned. In 1931 the Theater Lighting Committee[3] reported the results of a rather comprehensive series of tests in seven theaters. The screen illumination (without film but apparently with shutter running) was found to vary from 2.6 to 10 foot-candles, with brightnesses ranging from 2.2 to 9.3 foot-lamberts. Screen brightnesses of less than 2.8 foot-lamberts were found unsatisfactory due to the reduction of visual acuity. The higher values were found good in regard to visual acuity.

In the 1931 report to the International Commission on Illumination, the Japanese Secretariat Committee on Cinema Lighting recommended[1] a screen illumination of 9.3 foot-candles, presumably without film or shutter. This recommendation was based upon the assumption of an intensity of 0.18 foot-candle for the general theater lighting. Under these conditions, picture contrasts were not seriously affected. Higher values of screen intensity were stated to be unobjectionable. Measurements in eleven principal Tokyo theaters showed screen intensities varying from 3.1 to 9.3 foot-candles, with no correlation as to screen size. The average was 6.35 foot-candles, considerably below the recommended value. An idea of the screen brightnesses may be obtained from the fact that some of the screens were of American manufacture and, hence, about 80 per cent reflecting when new. In the report was also included a résumé of findings of a German National Sub-Committee, who stated that in ten German theaters the screen illumination varied from 6 to 16.8 foot-candles, at the screen centers, shutter and film conditions not mentioned. There was again no correlation with respect to size. The average intensity was 9.5 foot-candles. The reflectivity of the screens varied from 42 to 90 per cent, with 60 per cent as the average, and no correlation as to the light intensity used. The maximal screen brightness was 9.7, the average 5.8, and the minimal 2.6 foot-lamberts. In their table of data, the German Committee included a column showing the "required" screen intensities in the various theaters, the screen widths, the theater seating capacities, and the projection distances. How the "required" illuminations were determined is not explained in the text of the available printed report. The required intensities ranged from 7 foot-candles for a screen 13.8 feet wide to 11.4 foot-candles for a screen 22.3 feet wide.

In 1932, the Projection Screens Committee[9] reported the results of some tests conducted at a meeting of the New York Section of the Society. The object of the tests was to determine the magnitudes of illumination (apart from contrasts, *etc.*) acceptable with films of two different types, one showing interior and the other exterior scenes. No general theater illumination was provided. It was found that judgments depended somewhat upon the visual accommodation level of the spectators, but that, in general, considerably higher illumination was desirable in the case of the outdoor scenes. A brightness of 17 foot-lamberts was not generally regarded as excessive. For the film showing interior scenes, brightnesses of 7 to 11.5 foot-lamberts were generally acceptable. Time did not permit a more thorough series of tests, and the judgments showed some discrepancies, apparently due to the sequence in which the various lighting levels were presented to the observers. The optimal brightness indicated by the tests was 12 foot-lamberts. This value was not found to be critical, and a variation of nearly 50 per cent on either side was at least tolerable under the proper circumstances. All the data were obtained with the shutter running but without film. The recommended value is higher than is normally used.

Before leaving this phase of the subject, a brief résumé of the data will be attempted. Values of screen illumination ranging from about 1.5 to 20 foot-candles have been regarded as satisfactory at one time or another (these values are with shutter running, obtained from the data given above by applying the proper corrections). Taken as a whole, the data are scant, inconclusive, and insufficiently substantiated, so that no definite recommendations may be formulated from them. The lower values do not now represent good practice. Many of the later data fall in the range of 8 to 12 foot-candles, recommended for interiors by illuminating engineers, as previously mentioned. This may be a coincidence, but a tenable supposition is that some relation exists between the two situations. Brightness values of pictures projected upon normal diffusing screens within this range of incident light intensity approximate brightness values found desirable for interiors. It would appear reasonable to infer that such conditions in the theater are not far from correct. Upon the basis of practical considerations, we arrive at the same conclusion. Practice evolving through years of experience is likely to be at least approximately correct.

VARIATION OF BRIGHTNESS WITH SIZE OF SCREEN

A question that frequently recurs in the literature concerns the variation of required brightness with the screen size and the distance from which the screen is viewed. Put another way, this question involves the apparent size of the screen and its images, as measured by the solid angles subtended at the eye, in relation to the brightness of the surroundings. It will be remembered that the surface brightness of a screen is independent of viewing distance except for atmospheric absorption. Subjective impressions of brightness decreasing with distance are due to other variables. From our own everyday experience, as well as from the recommendations of illuminating engineers, we know that for good vision, small objects require higher illuminations than large objects. We might expect that higher screen brightnesses would be desirable for those at the rear of the theater, since the screen images appear smaller. Judging from the scant published information,[8,9,10] that has been found to be the case. It has also been generally conceded that smaller screens should be more brightly illuminated than larger ones. These two phases of the same fundamental question must be considered together. Unfortunately, in the past there has been a tendency to treat them separately. As a result, what few data there are lack definite quantitative significance, and may even appear superficially contradictory.

As mentioned above, Kunzmann in 1918 published a curve showing the required candle-power *vs.* the screen size, more light per unit area being needed for the smaller screens.[6] The variation shown was comparatively small, about 1.3 to 1.0 for a variation of screen width of 1 to 2. No reasons for the variation were advanced. The brief report of the German National Sub-Committee on Cinema Lighting,[1] already mentioned, cited data on specific theaters. The two extreme cases will be described: The smallest screen was 13.8 feet wide, and, with a projection distance of 49.2 feet apparently required an illumination of 7.05 foot-candles. The largest screen was 22.3 feet, the projection distance being about 151 feet and the required light intensity 11.4 foot-candles (shutter and film conditions not mentioned). It will be noted that the ratio of screen widths is the same as that of the required illumination; *i. e.*, about 1.0 to 1.6. The influence of projection distance is not stated, nor is it apparent from the data. Similar relations exist in the other cases, which fall between these two extremes. The required illumination increases directly with the screen width. No reasons for this are presented. Kunzmann's curve varied in the opposite direction, in agreement with other experience in this country. In the discussion following a report of the Projection Screens Committee,[9] Farnham stated that for an increase of screen width from 4 to 22 feet, a ratio of 1.0 to 5.5, the screen brightness could be reduced to a half or a third of the value required for the small size.

The factor of viewing distance considerably alters the situation, however. A large or small screen apparently requires a smaller or greater light intensity, depending upon the viewing distance. The figures just presented exclude this factor, and hence definite conclusions can not be drawn. The literature contains references to the desirability of increased brightness at greater viewing distances, but no quantitative data seem to be available. In any case, it is difficult to see how any allowance for this factor could be made practically in existing theaters. It seems impossible to design screens to have special reflection characteristics in different directions, with each unit of area different in its directional properties. So far as good engineering practice is concerned, it should suffice to choose the screen size as a function of maximal viewing distance. The size then would determine the distance of the nearest seats. With these precautions taken, the range of the solid angle subtended by the screen would be approximately the same from theater to theater. The brightness of the screen may thus be made relatively uniform for all theaters. This conclusion is a theoretical one, but is at least partially substantiated by practice. One supplier of projection equipment has stated that his firm attempts to follow this principle.

BRIGHTNESS OF SCREEN FRAME

The brightness of the screen frame is the last item to be discussed in the present analysis. A projected picture should have some definitive border, for esthetic reasons, to promote attention and to reduce "jumpiness" of the picture. These requirements must be met without introducing too great a contrast in the field of vision. According to Jones,[2] a border of neutral gray surrounding the screen is more pleasing than is a black one. A black border is more likely to give rise to a feeling of visual discomfort because of excessive contrast with the projected picture. Jones's recommendation was that the border should be at least $^1/_{1000}$, preferably $^1/_{500}$, as bright as the screen highlights. Since the illumination incident upon the borders is somewhat less than that upon the screen proper, the reflecting power of the border should be somewhat greater than $^1/_{500}$ that of the screen. With black velvet borders, the possible contrast has been estimated to be about 1 to 10,000.

The Theater Lighting Committee also advocated that screen surroundings have appreciable reflecting power.[3,8] Black borders were found to be acceptable in relatively narrow theaters. Comfortable conditions, apparently regardless of width, were obtained with gold, yellow, or similar surroundings about the screen. The brightness of the surroundings was about 0.047 foot-lambert, as against approximately 100 times that for the screen.

CONCLUSION

Practical considerations lead us to believe that there is nothing radically wrong with the values of theater and screen illumination in common use. If there were, reports of discomfort would be a great deal more frequent than they are. This observation is a comforting one, but does not warrant the cessation of further investigation. It merely gives us some assurance that we may temporarily halt at our present position while additional information is gathered. In the meantime, some improvement may be made in theaters at present by stricter application of the recommendations already made by qualified authorities, remembering that good illumination results only from proper integration of a group of interdependent factors.

(*For discussion, see p. 543*)

REFERENCES

[1] Report of the (Japanese) Secretariat Committee, *Proc. of the Internat. Comm. on Illum.*, Cambridge (England), Eighth Session (September, 1931), p. 380.

[2] Jones, L. A.: "The Interior Illumination of the Motion Picture Theater," *Trans. Soc. Mot. Pict. Eng.*, **IV** (1920), No. 10, p. 83

[3] Report of the Theater Lighting Committee, *J. Soc. Mot. Pict. Eng.*, **XVI** (Feb., 1931), No. 2, p. 239.

[4] Dennington, A. R.: "Projection of Motion Pictures by Means of Incandescent Lamps," *Trans. Soc. Mot. Pict. Eng.*, **I** (1917), No. 5, p. 29.

[5] Burrows, R. P., and Cardwell, J. T.: "Light Intensities for Motion Picture Projection," *Trans. Soc. Mot. Pict. Eng.*, **I** (1917), No. 5, p. 32.

[6] Kunzmann, W. C.: "Carbon Arc for Motion Picture Projection," *Trans. Soc. Mot. Pict. Eng.*, **II** (1918), No. 7, p. 20.

[7] Report of the Theater Lighting Committee, *Trans. Soc. Mot. Pict. Eng.*, **XII** (1928), No. 34, p. 549.

[8] Report of the Theater Lighting Committee, *J. Soc. Mot. Pict. Eng.*, **XIV** (April, 1930), No. 4, p. 441.

[9] Report of the Projection Screens Committee, *J. Soc. Mot. Pict. Eng.*, **XVIII** (Feb., 1932), No. 2, p. 242.

[10] Richardson, F. H.: "Difficulties Encountered in the Attempt to Standardize Theater Screen Illumination," *Trans. Soc. Mot. Pict. Eng.*, **VIII** (1924), No. 18, p. 93.

JOINT DISCUSSION OF

A REVIEW OF PROJECTOR AND SCREEN CHARACTERISTICS, AND THEIR EFFECTS UPON SCREEN BRIGHTNESS*

by

A. A. COOK

and

AN ANALYSIS OF THEATER AND SCREEN ILLUMINATION DATA**

by

S. K. WOLF

MR. LESHING: I am somewhat disappointed in what I have heard this morning at this meeting. The language I speak is somewhat different from yours. For me, logarithms do not exist. What I am concerned with primarily are the things that we all do; but some of us dilute our doings with so many words that we forget the substance. I heard here today things that I really could not understand, and other things that I understand only too well.

Take, for instance, the statement that there is nothing wrong with projection today. That is a point upon which I shall have to disagree. I brought a print of *Metropolitan* from Hollywood which I thought was a good print from an exceptionally well photographed negative. When projected upon the screen at the Radio City Music Hall, the picture which in Hollywood was excellent, was so bad as to be almost unrecognizable. It was necessary to make a new print having considerably greater contrast, to suit the projection conditions of the Music Hall.

I admit I was bewildered. Imagine what happens in the local theaters throughout this great country when we send out our prints. We talk about standardizing printing; we tell ourselves that the processing today is quite good; we say that projection is all right; and then project the film upon the screen without knowing what the result will be.

If the Society is going to spend most of its time on theoretical matters and very little on practical suggestions to the industry, the usefulness of the motion picture engineers will be negligible. I say that because I have the interest of the Society at heart. I know, in the past, the standards of the Society were adopted and did a great deal to improve motion pictures. Out on the Coast I believe we are making a little better progress because we talk practical things—how to show the product we sell to the public. What I should like to see the Society do is to adopt a standard of illumination. Do not say that 8 to 12 candle-power is all right. It is not right, when a picture that looks good upon one screen will look bad upon another. And besides, there are many other factors involved besides the illumination on the screen.

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* See p. 522.

** See p. 532.

We make better pictures in spite of ourselves. The stock is much better; there is no question about that. The cameras are much better. With the advent of sound we began to learn the *ABC*'s of processing film. But the main thing, the projection of the film, the presentation of the finished product to the public, is in a very poor state. If I can not be sure that a print when projected in New York in a theater as modern as the Music Hall will be equally as good as it was when projected at Hollywood, then projection practices are not what they should be.

MR. JONES: Sometimes it is good for one to have some criticism, and very severe criticism. However, I should like to point out that we are at least making an attempt; we are trying to make a start. Perhaps some of us have not had the long years of experience that Mr. Leshing has had, and we have yet to learn to walk before we can run. But I can assure Mr. Leshing that the Society is doing and wants to do all that it can to contribute to practical conclusions. We may start in a different manner, but I believe we shall arrive, and will try to do so as promptly as possible.

MR. SCHLANGER: The disappointing quality of the picture projected at the Music Hall is directly due to the great viewing and projecting distances. Such a condition emphasizes the need of establishing correct standards of viewing distance, screen brightness, visual acuity, *etc.* Satisfactory results were obtained when the print was projected in the Hollywood review room because the film was magnified during projection only to a comparatively small extent. The projection and viewing distances were short. On the other hand, in the great Music Hall auditorium, the picture was magnified to such an extent as to weaken and dissipate the blacks, thereby losing contrast and picture quality. An exact understanding of proper viewing distance and illumination levels would obviate the uncertainty mentioned by Mr. Leshing.

Which course are we to follow? Are we to take into consideration the existing theaters having viewing distances totally incorrect and build equipment to compensate for the faults of yesterday, or establish proper standards for new or altered theaters? There is now considerable activity in theater building, but the new and altered theaters will be erected properly only if the Society will help to establish the proper theater shape.

It has been stated that the patron does not complain of poor viewing conditions. The truth is that he does not usually *voice* his complaints. There is no doubt that theaters having better viewing conditions will be patronized the more, other things being equal. A patron will sit in poor seats only when he has no other choice, and will make every possible effort to obtain a better seat in spite of the annoyance of having to do so.

There has been a tendency to increase the screen illumination, due to the excessiveness of the viewing distances, and manufacture all kinds of equipment to do so. As a result, the forward half of the orchestra floor is rendered useless, because the brightness of the screen is too great for close viewing, and suits only the last few rows of seats. We shall have to choose between manufacturing equipment for obsolete theaters or gradually working toward the kind of equipment that will fit the correct and proper standard conditions for new and altered theaters.

MR. TASKER: In the course of being practical we must recognize, as Mr. Schlanger has indicated, that there are so many factors that it is difficult to put one's finger immediately upon the thing or things that should be modified in order to accomplish what we want to accomplish. It is important that we recheck each of the factors. Perhaps the projector is not able to do a good job of projecting. That should be checked. We refer also to practical experience—the fact that you found on the West Coast adequate projection for the picture you brought with you. As a point of information, where did you find that the projection was adequate? Was it in all, or several, of the theaters in Los Angeles; or was it only in the review room of the studio, which may possibly have had characteristics slightly differing from those of the Music Hall?

MR. LESHING: Our review rooms are fairly uniform, and average about 11 foot-candles in intensity. At the Music Hall it is 7.

MR. TASKER: Was that the principal fault?

MR. LESHING: It was, I believe, the principal cause of the flatness of the picture upon the screen, and that is why the higher contrast picture with the same density solved the problem.

Far be it from me, gentleman, to say that I do not appreciate or value all the scientific research you do. You could not do the marvelous things you have done without all this preliminary scientific work. What I want to emphasize is, do not go up too high. Keep your feet upon the ground, even if you keep your heads in the clouds. I believe that you are attacking the problem from the farthest point. Most likely you are right—but not from the producer's standpoint, because the producer is not really interested in the theory; he is interested in the product he is selling.

All over the country we hear complaints about release prints. A lot of money is being spent on the West Coast to make pictures technically better. We build expensive sets and pay large salaries to men who can offer us just a little more than the other fellow; yet the final result goes out as a poor print with poor projection. It is not only a question of prints. Prints could be standardized throughout the country within a short time, with very little effort. But that can not be done until projection is standardized, and I believe that some form of standard can be set up right now that will not entail changing all the equipment.

MR. TASKER: That, I believe, was the thought behind the original suggestion that screen illumination be tentatively set at somewhere between 9 and 12 foot-candles. Perhaps the margins were too wide, but it was recognized, even then, that the theaters vary and that there is an upper limit to what the present equipment can provide. Furthermore, there is great reluctance on the part of those theaters that easily exceed the limit to come down to it.

Perhaps you might conclude from your experience at the Music Hall that the intensity in all theaters and reviewing rooms should be reduced to 7. It seems a shame to reduce all the theaters, if a bright screen is desirable, to the lowest level in order to attain uniformity. I believe, therefore, that there is some justification for studying the auxiliary factors comprehensively in order to arrive at what should be our highest goal. All the work of the Committee is aimed toward a better specification of screen brightness and, consequently, toward giving you the opportunity of making the print densities and contrasts do the best possible job. I hope we shall move rapidly toward that end and with your good aid and cooperation.

MR. HARDY: I am just a little fearful that Mr. Leshing may take back to

Hollywood the wrong picture of what has occurred at this meeting. This is a meeting of technical experts, and the language used is the shorthand of technical expression. We understand one another in those terms and it is a convenience to use the terms. I do not think it was the intent of this meeting to arrange any general set of recommendations for the industry. That can be brought about only after the subject has been discussed in all its phases.

One difficulty is that scientific results come slowly. Science insists upon the fundamentality of the result and it takes time to collect the fundamental data. The charge that is always made against the scientist is that he deals with things that are not practical. We must steel ourselves to that charge. I imagine that at one time when an astronomer studied the spectrum of the sun and discovered a new spectral line and gave the name of helium to the element that produced it, he was regarded as a rather impractical sort of fellow. Later when helium was discovered upon the earth and was used to fill dirigibles, it was regarded a very practical application.

Since the introduction of sound, the motion picture industry has adopted a great many concepts that before the advent of sound were regarded as very theoretical. Now that industry has adopted them, they have become very practical, indeed, and I think, therefore, that we can look forward to the adoption of many of the ideas that have been expressed here today. The language can, of course, be simplified. The logarithms do not have to be mentioned; the results can be put into very simple terms.

MR. SETTE: One of the statements that I read from Mr. Wolf's paper appears to have been taken as more inclusive as well as more conclusive than it was intended to be. The statement was: "Practical considerations lead us to believe that there is nothing *radically* wrong with the values of theater and screen illumination in common use."

Although it was not made clear, the statement was intended to refer mainly to the visual comfort of the audience observing the performance. Our impression has been that complaints in that respect are not so common as they would be were the situation really bad. If the scenic values of a picture are partially lost in projection, that is something else again, and is not necessarily due to inadequate screen illumination. If the latter were the case, the available data would indicate that the effect would vary with viewing distance, and that satisfactory conditions would obtain for the nearer seats, except for woefully inadequate illumination. Articulate complaints regarding poor contrasts or other scenic qualities of a projected picture would depend upon the level of appreciation to which the public has been educated. Engineers actively engaged in motion picture work would be more consciously critical and would demand a closer approximation to perfection, as Mr. Leshing does.

Referring once more to the statement to which exception was taken, it is evident from its form and from the associated text that it was not intended to apply with syllogistic accuracy. The paper concluded that some improvement could be made in theaters by stricter application of already existing information.

In regard to Mr. Schlanger's remarks as to poor observation from the rear of large theaters, I fail to see how we can do much about it in existing theaters with available equipment. In future theaters, careful architectural design can do much to remedy the condition. The problem is a universal one, and should be as serious in auditoriums, stadiums, *etc.*, as it is in motion picture theaters.

MR. SCHLANGER: Viewing distances can, and must, be reduced.

MR. MITCHELL: Mr. Cook, does your formula apply to incandescent illumination? As I understood your statement, you referred primarily to 35-mm., where the size of the aperture was one factor and the size of the arc crater another. Would the formula apply to 16-mm.?

MR. COOK: When you speak of incandescent lamps, there is another thing to be taken into consideration, and that is the fact that the tungsten source is not a perfectly solid one. I have no figures here on the instrinsic brightness of tungsten, but I believe it is of the order of 27 candles per square millimeter. (The figure should be 49–58 c. per sq. mm. for biplane lamps used with a mirror.)

The estimate of screen brightness that I have attempted covers only the use of arc lamps with standard 35-mm. apertures. By substituting new dimensions for other sources or aperture sizes it could be made to apply to tungsten lamps or to 16-mm. film.

MR. MITCHELL: Mr. Tuttle, has any consideration been given to using your test apparatus to check distribution across the screen? I should like to refer again to the investigations that are being conducted by the Non-Theatrical Equipment Committee. In our last report we summarized the German recommendations, in which it is stated that the range of brightness from the center to the side of the screen should be fifty per cent. In the work of my company we have tended to reduce the variation to fifteen per cent, which is quite a difference. Although we have no exact data, I believe it is recognized that if one is close to the screen, he can endure a hotter spot at the center of a picture than if he is farther away.

I offer the suggestion that possibly some kind of movable vignette might be used with the test-screen to obtain some comparative data as to the most desirable distribution of light across the screen. I feel that this matter is of greater importance than is generally recognized.

MR. TUTTLE: I think Mr. Mitchell's suggestion is very interesting. We shall consider it.

DENSITY MEASUREMENTS OF RELEASE PRINTS*

C. M. TUTTLE**

Summary.—*Data regarding certain transmission characteristics of release prints are necessary to the work of the Projection Screen Brightness Committee. This paper lists the results of such measurements without detailed discussion of their significance. The apparatus used is fully described.*

As a part of the program of the Projection Screen Brightness Committee,[1] a number of density measurements of current release prints have been made. The purpose of making these measurements has been to supply data for the use of the Committee in its efforts to formulate a proposal for a standard of brightness. For this purpose, the data that appear to be significant are measurements of maxima and minima of density, average or total frame density, and density of areas of principal interest. The latter, which has been named "face value" by Palmer,[2] will henceforth be referred to as *F* density.

APPARATUS AND DATA

Two distinct pieces of apparatus have been used in this work. Sensitometric interpretation of the data requires that maximum and minimum densities shall be determined with a standard diffuse densitometer. From such statistical data, it should be possible to answer the question of how much of the positive characteristic is being used by the laboratories in making released prints. From a knowledge of this fact, it will be possible to state definitely to what degree the laboratory can accommodate its product to the needs of the theater.

Use of the data by those dealing with the problem of screen brightness, from the point of view of physiological optics, requires that maximum, minimum, average, and *F* density values be determined under conditions that are effective in the theater.

For the first requisite, a standard Eastman circular wedge den-

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** Eastman Kodak Co., Rochester, N. Y.

sitometer has been used. For the second set of values, a special "densitometer," shown in Fig. 1, has been set up. In this instrument, an optical system commonly used in theater projection has been copied as closely as possible. The dimensional data for the set-up are given in the illustration.

A concentrated filament light-source was substituted for the arc lamp customarily used in the theater, because of the difficulties of density measurement with an arc. For convenience, the throw was shortened and the film-to-objective distance increased. The actual dimensions of the projected picture were reduced to 2 ft. by 2 ft. $8^1/_2$ inches. In the plane of the projected image, a photocell of the barrier type is located. The cell is movable in this plane so that any area of the picture may be selected for measurement. The sensitive area of the cell was diaphragmed to a $^7/_{16}$-inch circular opening. Since the image magnification is about 40, the measured area corresponds to a circle of about 0.01 inch in diameter on the film. Readings from a second cell so located that it can be placed over the lens to measure the total flux in the beam with and without the film in place is used to obtain the total density values.

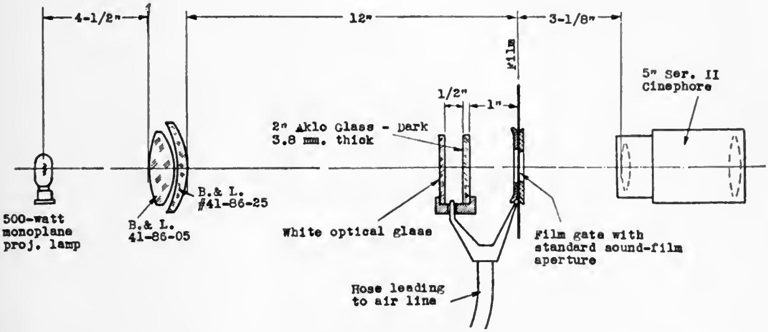

FIG. 1. Optical system used in making projection density measurements.

To provide a measurable image intensity without burning the film in the gate required the insertion of a piece of heat-absorbing glass between the condenser and the gate. Both this glass and the film itself are cooled by streams of air supplied by two properly located fish-tail nozzles.

While it is unfortunate that theater projection conditions can not be exactly duplicated in this set-up, the author feels confident

TABLE I

Typical Set of Observations on Miscellaneous Release Prints

Scene Number	Classification	$D_{\text{max.}}$ Diffuse	$D_{\text{max.}}$ Projection	$D_{\text{min.}}$ Diffuse	$D_{\text{min.}}$ Projection	Maximum Contrast Projection	Face Density Projection	Average Density Projection
1	*ICU*	1.84	2.45	0.20	0.26	2.19	0.52	1.23
2	*ILS*	1.72	2.16	0.17	0.30	1.86	0.57	1.02
3	*ES-CU*	1.52	2.09	0.50	0.71	1.38	..	1.23
4	*ICU*	1.45	1.97	0.45	0.52	1.45	0.81	1.13
5	*ECU**	1.86	2.54	0.78	0.95	1.59	1.08	1.68
6	*IS-CU*	2.09	2.65	0.65	0.76	1.89	1.19	1.28
7	*ES-CU*	2.10	2.65	0.35	0.41	2.24	1.40	1.90
8	*ES-CU*	1.50	1.90	0.30	0.39	1.51	1.06	0.67
9	*ILS*	1.65	2.18	0.17	0.22	1.96	1.29	1.57
10	*IS-CU*	1.72	2.22	0.52	0.60	1.62	0.75	1.36
11	*IS-CU*	2.02	2.64	0.15	0.18	2.46	0.94	0.99
12	*IS-CU*	1.66	2.14	0.20	0.26	1.88	0.62	1.18
13	*IS-CU*	1.63	2.21	0.30	0.44	1.77	0.68	1.00
14	*ELS**	1.72	2.34	0.40	0.60	1.74	..	1.36
15	*IS-CU*	1.52	2.15	0.30	0.30	1.76	0.71	0.95
16	*IS-CU*	1.53	2.04	0.23	0.35	1.69	0.81	0.87
17	*ICU*	1.66	2.04	0.30	0.36	1.68	0.95	1.00
18	*ICU*	1.74	2.28	0.20	0.22	2.06	0.43	0.94
19	*Title*	1.55	2.11	0.18	0.27	1.84	..	1.13
20	*ICU*	1.50	2.04	0.36	0.64	1.40	0.75	0.88
21	*ILS**	2.10	2.57	0.50	1.05	1.52	1.40	1.64
22	*ILS*	1.70	2.30	0.35	0.43	1.87	..	1.66
23	*ICU*	2.10	2.52	0.45	0.52	2.00	1.60	1.16
24	*IS-CU*	1.52	2.10	0.30	0.37	1.73	0.95	1.09
25	*ELS*	1.72	2.22	0.25	0.40	1.82	0.57	0.95
26	*ICU*	1.65	2.27	0.55	0.75	1.52	0.78	1.28
27	*ICU*	1.72	2.19	0.20	0.29	1.90	0.58	0.91
28	*ICU*	1.48	2.30	0.78	1.03	1.27	0.51	0.80
29	*ICU*	1.94	2.54	0.20	0.23	2.31	0.71	0.94
30	*IS-CU*	1.58	2.04	0.28	0.48	1.56	0.93	0.85

Legend: *CU,* close-up.
S-CU, semi-close-up.
LS, long shot.
E, exterior.
I, interior.
* night scenes.

that the modifications described above introduce no considerable error into the density measurements.

A list of all the results obtained in this experiment would be too voluminous to justify printing in the JOURNAL. However, a typical page of data is shown in Table I, with a legend explaining the nature of the scenes. It was at first thought that some correlation might be found between the scene type and its optical characteristics. If any exists it has not yet been uncovered. In Table II an attempt has been made to give the salient points regarding all the data.

When dealing with statistical data of this nature, graphical presentation offers a ready means of getting a composite picture of results. A few of the possibilities are illustrated in Fig. 2, in which the projection density values of $D_{\text{min.}}$, $D_{\text{av.}}$, $D_{\text{max.}}$, and D_F are shown as functions of the frequency with which the various values occur.

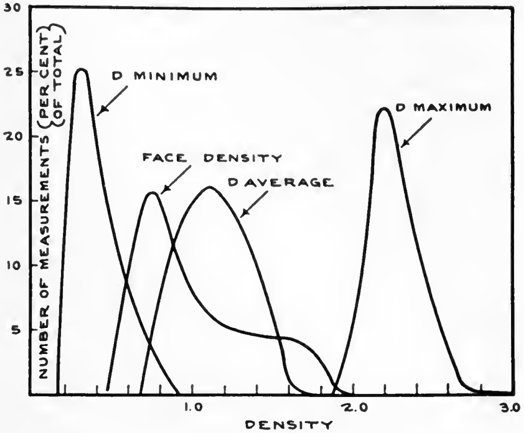

FIG. 2. Frequency distribution of projection density measurements.

TABLE II

Summary of Data Regarding Release Print Measurements

	Diffuse	Projection
Highest $D_{\text{max.}}$ measured	2.46	3.20
Lowest $D_{\text{min.}}$ measured	0.15	0.19
Highest $D_{\text{av.}}$ measured	..	1.90
Lowest $D_{\text{av.}}$ measured	..	0.67
Highest D_F measured	..	1.60
Lowest D_F measured	..	0.60
Highest contrast scene	..	2.45
Lowest contrast scene	..	1.38
Average $D_{\text{max.}}$	1.85	2.40
Average $D_{\text{min.}}$	0.33	0.43
Average $D_{\text{av.}}$	..	1.15
Average D_F	..	0.99
Average contrast	1.52	2.00

DISCUSSION

Analysis of the significance of these data is beyond the scope of this paper. A few general statements concerning the sensitometric interpretation are, however, of some interest.

There is a remarkable absence of scattered light or flare in the projection optical system. This is evidenced by the constancy of the ratio between diffuse and projection density values. If an appreciable amount of scattered light were present, the high print density values as measured in the projection system would be decreased. Actually, the ratio of diffuse to projection density is about 1.3 for the whole range of values. The exceptions are almost certainly caused by experimental error resulting from the difficulty of locating identical scene areas in both densitometers.

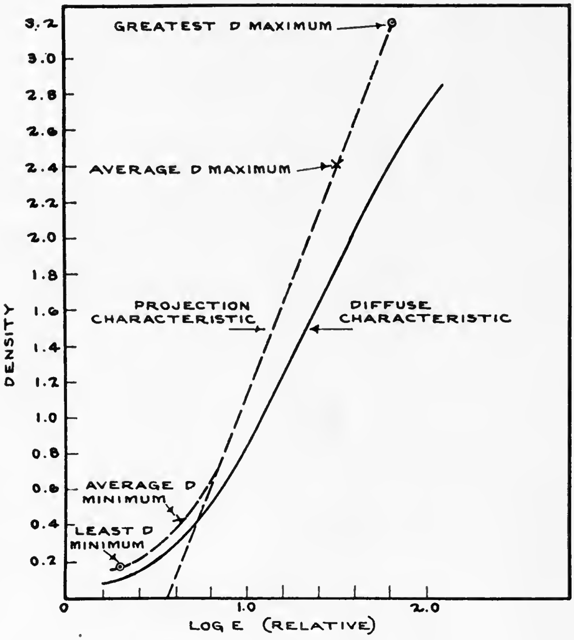

FIG. 3. The characteristic curve used in making release prints.

Fig. 3 shows, as a solid line, a typical characteristic curve for a positive emulsion developed to a diffuse gamma of approximately 2.0, the gamma to which sound pictures are developed by the laboratories.[3] The picture projection characteristic corresponding to this diffuse characteristic is shown by the broken lines.

Taking the data from Table II, one finds that the portion of the positive characteristic identified by crosses, *i. e.*, from 0.43 to 2.4, is used for the average release print. The extreme minimum of the data so far at hand is 0.19 and the extreme maximum is 3.20. These values are marked by circles. On the average, then, it appears that release prints use all the lower straight-line portion of the characteristic curve and a part of the toe region. In extreme cases picture highlight densities approximate the minimum obtainable with any gradient.

It is obvious that while the laboratories have ample opportunity to make darker prints without going into the shoulder region, nothing can be done to make them lighter without seriously altering tone reproduction. A substantiating proof of this is the fact that in no case does the "face value" drop appreciably into the toe region. The average value is close to unity.

The author wishes to thank various members of the Projection Screen Brightness Committee who have supplied samples from current release prints, and the Bausch and Lomb Optical Company who have supplied what is believed to be a typical projection optical system.

REFERENCES

[1] Report of the Projection Screen Brightness Committee, *J. Soc. Mot. Pict. Eng.*, **XXV** (Sept., 1935), No. 3, p. 269.

[2] PALMER, M. W., AND RICHARDS, A. J.: "A Proposed New Method of 'Timing' Negatives," *J. Soc. Mot. Pict. Eng.*, **XV** (Aug., 1930), No. 2, p. 181.

[3] Bulletin of the Research Council: *Acad. Mot. Pict. Arts & Sciences*, July 27, 1935.

PHOTOMETRY AND BRIGHTNESS MEASUREMENTS*

R. P. TEELE**

Summary.—*A general discussion of the subject of photometry and methods of measuring brightness. Descriptions are given of the apparatus and methods used in measuring luminous intensity, luminous flux, transmission and absorption, and brightness. In an appendix are listed definitions of the various units and terms involved in photometry and the measurement of the various photometric quantities.*

I. INTRODUCTION

Photometry is, as its name implies, the measurement of light. Light may be defined as luminous radiation, that is, radiation that is capable of producing in the human eye the sensation of vision. With the exception of various methods of physical photometry, all light measurements are made by the human eye. Even in physical photometry the aim is to obtain an instrument that will give results in accord with those that would be obtained visually.

Because the eye is the final arbiter for all ordinary photometric purposes it is of interest to give some description of its construction and mode of working. The eye is an ellipsoidal, nearly globular organ about 23 millimeters in diameter. It is enclosed in a tough outer skin (termed the sclera) which is opaque to light. This is replaced at the front of the eye by a transparent cartilaginous lamina (termed the cornea) which is more convex than the sclera. Under the sclera is a second coat (termed the choroid) which consists almost entirely of blood vessels and nerves. In the front of the eye the choroid is replaced by the iris which forms an adjustable shutter. The innermost coating of the eye is called the retina and consists chiefly of nerve fibers which spread out from the optic nerve.

The interior of the eye is filled with three transparent media. The first is termed the aqueous humour and fills the space between the cornea and the lens, or second medium. The lens, situated just behind the iris, is double-convex, with the posterior surface of greater

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* Presented at the Fall, 1935, Meeting at Washington, D. C. Publication Approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

** Bureau of Standards, Washington, D. C.

curvature than the anterior. The space between the lens and the retina is filled with a thin jelly termed the vitreous humour.

When an object is looked at, waves of light proceeding from its various points enter the eye at the cornea and are refracted by the various media so that an image of the object is formed upon the surface of the retina. The observer's concept of the image impressed upon the retina depends upon his interpretation of such images by mental processes involving tradition, memory, and experience. Vision is a combined physiological and psychological process. In photometry, observers whose eyes have quite similar characteristics may obtain markedly different positions of photometric balance, because the two observers form different mental pictures of the appearance that two illuminated surfaces must assume when they are "balanced" for making photometric measurements. This makes it desirable to use a substitution method whenever possible, especially when observers are called upon to judge the photometric equality of surfaces illuminated by lights of different color.

II. BASIC PRINCIPLES OF PHOTOMETRY

Regarded as a physical measurement, photometry depends upon two laws: (*1*) that the illumination of a surface by light emanating from a point-source varies inversely as the square of the distance between the source and surface; and (*2*) that the luminous energy received by a plane surface varies as the cosine of the angle of inclination of the normal to the surface to the incident ray. These two laws, the inverse-square law and the cosine law, can easily be shown to be true if a luminous point be regarded as the source of a system of spherical waves diverging from it as a center. The spherical area of any such wave as it travels outward from the source must increase as the square of its radius, and since its energy must be regarded as uniformly distributed over its surface, the surface-density of this energy must also vary inversely as the square of the radius of the wave (*i. e.*, the square of the distance from the source). Furthermore, since the direction of motion is always perpendicular to the wave-front, it follows that an elementary area can receive energy only in proportion to its area projected in that direction; that is, the surface-density of the energy received by any such area is proportional to $\cos\theta$, where θ is the angle between the normal to the surface and the direction of propagation of the incident wave.

The inverse-square law holds good only when the light-source is relatively small with reference to the distance from the source to the illuminated surface. The cosine law applies to any plane surface, so far as the incident light is concerned.

It is convenient for our purposes to consider the source and its energy together, in defining luminous flux and luminous intensity. The definitions adopted by the International Commission on Illumination in 1921 and 1924 are as follows:

> "*Luminous Flux* is the rate of passage of radiant energy evaluated by reference to the luminous sensation produced by it.
>
> "Although luminous flux should be regarded, strictly, as the rate of passage of radiant energy as just defined, it can, nevertheless, be accepted as an entity for the purposes of practical photometry, since the rate may be regarded as being constant under those conditions.
>
> "The *Luminous Intensity* (candle-power) of a point-source in any direction is the luminous flux per unit solid angle emitted by that source in that direction. (The flux emanating from a source whose dimensions are negligible in comparison with the distance from which it is observed, may be regarded as coming from a point.)
>
> "The *unit of luminous intensity* is the International Candle such as resulted from agreements effected between the three national standardizing laboratories of France, Great Britain and the United States of America, in 1909.[1] This unit has been maintained since that time by means of electric incandescent lamps in these laboratories, which continue to be entrusted with its maintenance."

The lumen is the *unit of luminous flux*. It is equal to the flux passing through a unit solid angle (steradian) from a uniform point-source of one candle, or to the flux incident upon a unit surface all points of which are at unit distance from a uniform point-source of one candle.

It should be noted that the expression "candle-power of a source" is indefinite unless it be specified as either the value in a single direction or the average value within a given region.

When luminous flux reaches a surface, we say that that surface is illuminated. The *illumination* at any point of the surface may be defined as the ratio of the flux incident upon the surface to the area of the surface, when the surface is uniformly illuminated. That is, the illumination at a point of a surface is the density of the luminous flux at that point. There are several units in which illumination is expressed, depending upon the units chosen to express the area. The unit most commonly used in American practice is the *foot-candle*, which is one lumen per square foot. Other units are the *phot* (lumen per square centimeter) and the *lux* or *meter-candle* (lumen per square meter). (See appendix for exact definitions.)

In defining illumination nothing has been said about the nature of the surface, because the illumination of a surface does not depend upon the nature of the surface. If a white and a black surface receive the same amount of flux per unit area they are equally illuminated even though they present quite different appearances to the eye, and although equally illuminated, the surfaces differ greatly in brightness.

The *brightness*, in a given direction, of a surface emitting or reflecting light is the ratio of the luminous intensity measured in that direction to the area of the surface projected upon a plane perpendicular to the direction considered. The brightness of a non-luminous surface depends both upon the illumination and upon the proportion of the incident light that the surface can reflect to the eye of the observer. The brightness of a surface is independent of the distance from which the object is viewed, since the flux entering the eye from a unit of area of the surface varies inversely as the square of the distance from the eye to the surface, and the superficial area of the retinal image varies in exactly the same manner.

The units commonly used for expressing brightness are the candle per square inch and the candle per square foot. There are also, of course, the metric units, in which the square millimeter, square centimeter, or square meter is used in expressing the area. These are defined later.

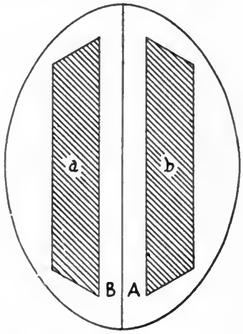

FIG. 1. Appearance of Lummer-Brodhun contrast photometer field.

(*a*) *Measurement of Candle-Power or Luminous Intensity.*—Candle-power as an entity is not measured in practical photometry. The brightness of a surface resulting when the surface is illuminated by the source under consideration is the criterion used in practical work. To evaluate the brightness of the test-surface it is necessary to compare the surface with the known or determinable brightness of some other surface. The device enabling the observer to compare the brightnesses of two surfaces is called a photometer.

Portable photometers are described in detail in another section of this paper. One of the most sensitive types of visual photometer is the Lummer-Brodhun contrast photometer. Fig. 1 shows the appearance of the field, while Fig. 2 shows the photometer cube employed in this type of photometer. The parts *A* and *a*, of the field, receive light from one surface, while the parts *B* and *b* receive light from the other surface. Referring to Fig. 1, when the brightnesses of the two surfaces being compared are the same, the two halves A and B have the same brightness, and at the same time the trapezoids a and b stand out in equal contrast to their backgrounds. The paths of the light from two surfaces S_1 and S_2 through a Lummer-Brodhun photometer cube are shown in Fig. 2. The two halves of the cube are in optical contact over the portions through which light reaches A and a. The light passing through a has to pass through the contrast strip C_1, a piece of optical glass which by reflection removes about 8 per cent of the light. Where the two halves are not in optical contact reflection takes place, and the light from S_2 reaches B and b, passing through a contrast strip C_2 before reaching b.

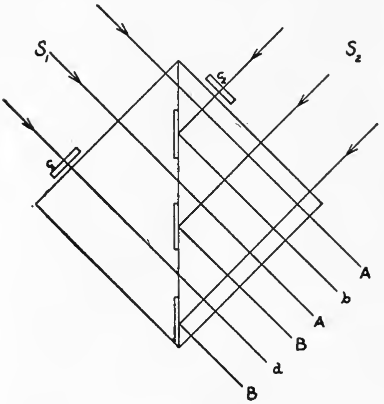

FIG. 2. Lummer-Brodhun cube.

Fig. 3 represents the paths of light in a photometer head. The Lummer-Brodhun cube is represented as a plain field divided in the center for the sake of simplicity. If two lamps, L_1 and L_2, illuminate opposite sides of the screen S, each of which is an opaque, diffusely reflecting surface, the light reflected from the two sides of S will pass to the eyepiece E by the paths shown. M and M are two reflecting surfaces, either mirrors or totally reflecting prisms. The two sides of S will be viewed in juxtaposition by the eye of the observer.

There are various ways of using a photometer for determining the candle-power of a lamp. The method employed at the National Bureau of Standards is one of substitution. Standard lamps are used to illuminate one side of the photometer screen, while the other side is illuminated by a comparison lamp at a fixed distance from the photometer screen. After several standards have been balanced on the photometer and their distances from the photometer screen recorded, the lamp being tested is placed in the same socket employed for the standard lamps, and the position at which the photometer is balanced is recorded. The inverse-square law is then used to determine the candle-power of the test-lamp. As already pointed out, this candle-power refers to a specified direction or average value in a definite region (usually in a specified direction or the average in a horizontal plane).

(*b*) *Measurement of Luminous Flux.*—The measurement of luminous flux necessitates the use of some form of integrator. The most desirable form of integrator is a hollow sphere, with a diffusely reflecting inner surface. It can be shown that such a sphere will integrate luminous flux.[2]

The brightness of a small area of the sphere wall, or the brightness of the outer surface of a diffusely transmitting window in the sphere wall, is compared with a comparison surface by means of a photometer. The window or area is screened from direct light from the source, but receives light by reflection from the other portions of the sphere. The various elements of uncertainty entering into the considerations of a sphere as an integrator make it undesirable to use a sphere for the absolute measurement of flux but do not detract in the least from its use when a substitution method is employed.

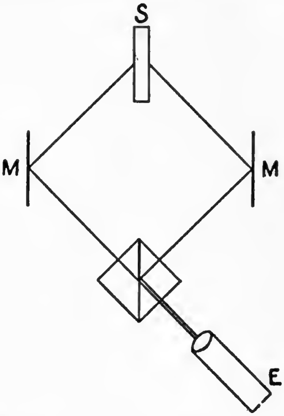

FIG. 3. Light paths in a photometer head.

(*c*) *Measurement of Transmission and Absorption.*—The *transmission factor* for any body is the ratio of the flux transmitted by the body to the flux incident upon it. The transmission factor of a colorless transparent plate is easily found by measuring the candle-power of a source with and without the plate between it and the photometer. When the body scatters or diffuses the light the transmission factor depends upon the angle of incidence. When the body is not colorless the transmission factor depends upon the spectral energy distribution of the incident light.

The transmission factor for a given optical system may be found by measuring the brightness of the image formed by the system when the object is a diffusing surface of known brightness. In this case the transmission factor is the ratio B_i/B_o, where B_i is the brightness of the image and B_o the brightness of the object.

When the body is colored the transmission factor should be obtained by computation from spectrophotometric data. The transmission factors for various wavelengths are measured with a spectrophotometer and the luminous transmission computed by a summation process for incident light of the particular spectral distribution of energy under consideration.

The *absorption factor* of any substance is the ratio of the flux absorbed by the body to the flux incident upon it. In practical photometry it is not possible to measure the absorption directly. When light is incident upon a body, part is reflected, part is absorbed, and part is transmitted. These three portions added together are equal to the amount of incident light. So we have $\rho + \alpha + T = 1$ where ρ is the portion of the incident light that is reflected, α is the portion absorbed, and T is the portion transmitted. When the transmission factor is measured it is often convenient to regard the reflected and absorbed portions together as a loss, *i. e.*, the part that is not transmitted.

(*d*) *Measurement of Screen Illumination.*—There are two problems that naturally arise when the performance of motion picture projectors is considered. One is screen illumination, and the other is the over-all efficiency of the light-projecting system.

Optically, motion picture projection apparatus consists essentially of a light-source and condensing lens, a photographic print upon a transparent film, a projection objective lens, and a screen. Auxiliary apparatus includes a rotary shutter, an aperture plate, and sometimes a mirror reflector. By combining suitable optical glasses in elements of proper thickness, surface curvature, and spacing, it is possible to obtain good definition, flatness of field, equally sharp images over the entire screen picture, and freedom from chromatic and spherical aberrations.

The average value as well as the uniformity of the screen illumination needs to be taken into account. Measurements of the illumination should be made at a sufficient number of points to obtain reasonably accurate data on these two questions.

To measure the illumination at a point it is necessary to place at that point a standard surface, which should be as nearly as possible a perfect diffuser. When the surface is to be viewed by reflected light, such surfaces as white blotting paper, plaster of Paris, magnesium oxide or carbonate, ground or depolished milk glass (opal glass), make good test-plates or standard surfaces. When the test-plate is to be viewed by transmitted light, as when using the transmitting test-plate of a Macbeth illuminometer or Sharp-Millar photometer, the surface most commonly used is one of milk-glass. For the general measurement of illumination when the light is incident at large angles to the normal it is necessary to use a so-called "compensated" test-plate in order to avoid errors. However, in screen illumination measurements the light is not incident at such angles, and there is no necessity for using a "compensated" test-plate.

The test-plate is calibrated by illuminating it by light from a standard lamp (usually standardized in terms of candles in a specified direction) or by using a reference standard. The brightness of the test-plate is balanced against the brightness of the comparison surface of a photometer, usually of the portable type. The angle at which the test-plate is viewed is nearly always left to the choice of the observer. As long as the test-plate is a nearly perfect diffuser and the angle of viewing is not excessive (not over about 25 degrees from normal), no important error is introduced. The scale reading of the photometer when the standard surface is viewed serves as the basis for computing the illumination falling upon the test-plate when the latter is placed at the point at which the illumination is to be measured. The scale on most portable photometers is graduated in terms of the inverse-square law, and scale readings are, therefore, directly proportional to the illumination or brightness of the comparison surface.

(*e*) *Measurement of Brightness.*—While illumination is a measure of the light received by a surface, brightness is a measure of the light emitted in any given direction. This light may be due to self-luminosity or to reflection.

A perfectly diffusing surface is one for which the candle-power per unit of area in any direction varies as the cosine of the angle between that direction and the normal to the surface. A perfectly diffusing surface appears equally bright in all directions. The flux emitted per unit of area by a perfect diffuser the brightness of which is I candles per unit area is πI lumens. This gives us another way of expressing brightness. In this alternative system the brightness may be defined as the total luminous flux emitted by a perfectly diffusing surface per unit of area. When the flux emitted is expressed in lumens and the area in square centimeters, the unit is called the *lambert.* This unit is inconveniently large; the thousandth part of it, or the *millilambert,* is a more practical magnitude. A surface emitting one lumen per square centimeter has a brightness of one lambert only in the case of a perfect diffuser. It is possible to express the brightness of any surface in any direction in terms of the brightness of a perfectly diffusing surface. If we say that a surface has a brightness of x lamberts when viewed in a certain direction, we mean that it has the same brightness as a perfectly diffusing surface emitting or reflecting x lumens per square centimeter.

Another unit of brightness is the *foot-lambert,* defined as the average brightness of any surface emitting or reflecting 1 lumen per square foot.

For a perfectly diffusing surface the flux system has the advantage that the brightness in foot-lamberts is numerically equal to the product of the reflection factor of the surface and the illumination in foot-candles. The disadvantage of the flux system is that it obscures the similar nature of brightness and luminous intensity.

When we measure the brightness of a reflecting surface we are measuring a quantity that depends upon the level of illumination, the reflection factor of the surface, and the angle at which the surface is viewed. The reflection factor, in turn, depends upon the angle of incidence of the light, the spectral energy distribution of this incident light, and the condition of the surface.

Let us consider the brightness in several special cases. When a source is viewed in a mirror we see the source only at one particular angle, and at that angle the brightness is simply ρB, where ρ is the reflection factor of the mirror for the particular angle of incidence.

If a perfect diffuser is viewed we have the conditions already discussed, in which the flux emitted per unit area is equal to πI. In terms of the flux received this becomes $\rho \pi I$, where ρ is now the diffuse reflection factor for the diffuser under the conditions in question.

For a given illumination the brightness of a matte or partly diffusing surface differs in general from that of a perfect diffuser, depending upon the angle of view. The departures are usually most marked at the angle of regular reflection and at very large angles from the normal, and when the angle of incidence is greater than 45 degrees. A theoretical treatment that agrees well with the actual conditions for a matte surface such as white blotting paper has been given by Bouguer[3] and extended by Berry.[4] It is assumed that a matte surface is composed of elementary mirrors the slopes of which are distributed according to the probability law. These considerations lead to the expression

$$B = B_0 \sec^2 {}^1/_2 \, (\theta - \theta') \sec \theta \sec \theta' \, e^{-a^2 \tan^2 {}^1/_2(\theta - \theta')}$$

B is the brightness at an angle θ', when the light is incident at an angle θ, θ' being in the plane of incidence, and B_0 is taken as the brightness when $\theta = \theta' = 0$.

(*f*) *Portable Photometers and Their Use.*—There are several portable photometers that may be used for brightness measurements. Detailed descriptions are given in various text-books and hand-books but only general descriptions will be given here.

The Macbeth illuminometer is supplied with complete equipment for the supply, control, and measurement of the current passing through the comparison lamp. A reference standard for recalibration and a diffusing surface are part of the apparatus supplied with the photometer. The optical device is a Lummer-Brodhun cube. An opal glass comparison surface is illuminated by a comparison lamp in a diaphragmed enclosure which is moved in a tube by a rack and pinion. An inverse-square scale is marked upon the rod moving the comparison lamp. Provision is made for inserting neutral filters to increase the range of the instrument. It is always possible to calibrate the Macbeth illuminometer so that the scale reads directly in foot-candles over a range of 1 to 25.

The reference standard consists of a lamp in a housing having a hole for inserting the sight-tube of the illuminometer so that the test-surface may be viewed. The illumination incident upon the test-surface when a predetermined current is passed through the lamp in the reference standard is known, and serves as the basis for calibrating or checking the readings of the illuminometer. The procedure for calibrating the illuminometer is to place the reference standard upon the test-surface and determine the comparison-lamp current that will make the instrument read directly.

This comparison-lamp current is maintained constant while measurements are being made. The test-surface is placed at the point where the illumination is to be measured and a photometric balance is obtained. The reading of the scale of the illuminometer gives the foot-candles at the point. It is desirable to view the test-surface at nearly the same angle as used in the reference standard (about 15 degrees). No appreciable error will be introduced, however, if angles of less than 25 degrees from the normal are used. The observer should be careful to avoid casting any shadow upon the test-surface while making the measurements.

Careful laboratory measurements of the test-surface can be made to determine its reflection factor for the conditions of view in the reference standard (normal incidence, 15-degree angle of view). When the photometer has been calibrated to read illumination in foot-candles, the reading of the scale multiplied by ρ/π is the brightness expressed in candles per square foot. To express the reading in candles per square inch the factor is $\rho/144\pi$.

A similar portable photometer is the Holophane Lightmeter. This photometer has a tube containing a flashlight battery, in one end of which tube the comparison lamp is mounted while a meter and rheostat are carried in the other end. An inverse-square scale is engraved upon the side of the tube. The method of use is similar to that of the Macbeth illuminometer. Some means of calibrating and checking the instrument are necessary, for which purpose a calibrated lamp and standard surface can be used.

Another photometer of the portable type is the Sharp-Millar. Two sizes are manufactured, the larger of which is semiportable and not of convenient size for such work as measuring screen illumination or brightness. The smaller size is not as easy to use as the Macbeth or Holophane photometers. The optical device is a pattern mirror in the small photometer and a Lummer-Brodhun cube in the larger size. The comparison lamp moves upon a track and the image of an index upon one side of the comparison-lamp housing falls upon an inverse-square scale on the side of the box that houses the photometer.

A transmitting test-plate can be used on any of these photometers but for measurements of motion picture screens the separate test-surface is preferable. Having a test-surface, the reflection characteristics of which are known, a projector and screen can be measured by taking two photometric readings at each point.

Place the test-surface at a point upon the motion picture screen at which measurements are to be made and obtain a photometric balance. This reading gives the illumination in foot-candles (assuming that the photometer has been previously calibrated) and, by multiplying by ρ/π (for candles per square foot), the brightness of the test-surface. Without changing the position of the photometer remove the test-plate and again obtain a photometric balance. The ratio of the two readings is the ratio of the screen brightness to the brightness of the test-surface. The fact should not be overlooked that the brightness that is measured is dependent upon the angle of incidence of the light upon the screen and the angle of view. The voltage across the lamp in the projector should be maintained at a constant value during the test. If the lamp is operated at the rated voltage its life is short, and for extended tests a value considerably less than the rated voltage should be used and the lamp calibrated for that voltage. The manufacturer can supply data for determining the ratio of the light output of a lamp at two different voltages. The projector should be run at the rated speed but without film when making the tests.

The screen illumination per lumen of light output of the lamp is an indication of the efficiency of the projector. The screen brightness per foot-candle of screen illumination is an indication of the effectiveness of the screen in reflecting light to the observer's eye.

In making tests of motion picture screens it is well to remember that we are dealing with physiological-psychological phenomena and that all the conditions under which the data are taken should be recorded. Factors that may not be regarded as important today may be of considerable importance in view of new knowledge of the processes of vision learned tomorrow.

APPENDIX

Standard Nomenclature

Abstracted from Illuminating Engineering Nomenclature and Photometric Standards, approved American Standard, December 19, 1932, by American Standards Association.

(*1*) *Light.*—For the purposes of illuminating engineering, *light* is radiant energy evaluated according to its capacity to produce visual sensation.

(*2*) *Radiant Flux.*—Radiant flux is the time rate of flow of radiant energy. It is expressed preferably in ergs per second or in watts.

(*3*) *Luminous Flux.*—Luminous flux is the time rate of flow of light.

(*4*) *Lumen.*—The lumen is the unit of luminous flux. It is equal to the flux through a unit solid angle (steradian) from a uniform point-source of one candle, or to the flux on a unit surface all points of which are at unit distance from a uniform point-source of one candle. (For some purposes the kilolumen, equal to 1000 lumens, is a convenient unit.)

(*5*) *Luminous Intensity.*—Luminous intensity, of a source of light, in a given direction, is the solid-angular flux density in the direction in question. Hence, it is the luminous flux on a small surface normal to that direction, divided by the solid angle (in steradians) which the surface subtends at the source of light.

Mathematically a solid angle must have a point as its apex; the definition of luminous intensity therefore applies strictly only to a point-source. In practice, however, light emanating from a source whose dimensions are negligible in comparison with the distance from which it is observed may be considered as coming from a point.

(*6*) *Candle.*—The candle is the unit of luminous intensity. The unit used in the United States is a specified fraction of the average horizontal candle-power of a group of 45 carbon-filament lamps preserved at the Bureau of Standards, when the lamps are operated at specified voltages. This unit is identical, within the limits of uncertainty of measurement, with the International Candle established in 1909 by agreement between the national standardizing laboratories of France, Great Britain, and the United States, and adopted in 1921 by the International Commission on Illumination.

The maintenance of the adopted unit by means of incandescent lamps is a temporary expedient, pending the development of a satisfactory reproducible primary standard. It is expected that eventually the unit will be defined as a fraction of the luminous intensity of a black-body radiator under specified conditions.

(*7*) *Candle-Power.*—Candle-power is luminous intensity expressed in candles.

(*8*) *Illumination.*—Illumination is the density of the luminous flux on a surface; it is the quotient of the flux by the area of the surface when the latter is uniformly illuminated.

(*9*) *Foot-Candle.*—The foot-candle is the unit of illumination when the foot is taken as the unit of length. It is the illumination on a surface one square foot in area on which there is a uniformly distributed flux of one lumen, or the illumination produced at a surface, all points of which are at a distance of one foot from a uniform source of one candle.

(*10*) *Lux.*—The lux is the practical unit of illumination in the metric system, equivalent to the "meter-candle." It is the illumination on a surface one square meter in area on which there is a uniformly distributed flux of one lumen, or the illumination produced at a surface, all points of which are at a distance of one meter from a uniform point-source of one candle.

(*11*) *Phot.*—The phot is the unit of illumination when the centimeter is taken as the unit of length; it is equal to one lumen per square centimeter.

1 Foot-Candle = 10.764 Lux = 1.0764 Millipho

(*12*) *Quantity of Light.*—Quantity of light is the product of the luminous flux by the time it is maintained. It is the time integral of luminous flux.

(*13*) *Lumen-Hour.*—The lumen-hour is the unit of quantity of light. It is the quantity of light delivered in one hour by a flux of one lumen.

(*14*) *Brightness.*—Brightness is the quotient of the luminous intensity of a surface measured in a given direction by the area of this surface projected on a plane perpendicular to the direction considered.

In practice no surface obeys exactly the cosine law of emission or reflection; hence the brightness of a surface generally is not uniform but varies with the angle at which it is viewed.

(*15*) *Units of Brightness.*—The practice recognized internationally is to express brightness in candles per unit area of surface. The brightness of *any* surface, in a specified direction, can also be expressed in terms of the lumens per unit area from a perfectly diffusing surface of equal brightness.

When the brightness of a secondary source of light is calculated in candles per unit area from the illumination on that source, the constant π is usually involved. The calculations can be simplified by using units of brightness which are smaller by the factor π. This is equivalent to expressing the brightness in terms of the number of lumens per unit area from a perfectly diffusing surface of the same brightness.

(*16*) *Lambert.*—The lambert is a unit of brightness equal to the uniform brightness of a perfectly diffusing surface emitting or reflecting light at the rate of one lumen per square centimeter.

The lambert is also the *average* brightness of any surface emitting or reflecting light at the rate of one lumen per square centimeter. For the general case the average must be taken in a double sense, to take account of variation of brightness with angle of observation and also of its variation from point to point on the surface considered.

For most purposes the millilambert, 0.001 lambert, is the preferable practical unit.

Brightness expressed in candles per square centimeter may be reduced to lamberts by multiplying by π.

Brightness expressed in candles per square inch may be reduced to lamberts by multiplying by $\pi/6.45$, or 0.487.

(*17*) *Foot-Lambert.*—The foot-lambert is a unit of brightness equal to the average brightness of any surface emitting or reflecting light at the rate of one lumen per square foot, or the uniform brightness of a perfectly diffusing surface emitting or reflecting light at that rate.

The average brightness of any reflecting surface in foot-lamberts is therefore the product of the illumination in foot-candles by the reflection factor of the surface. One foot-lambert is equal to 1.076 millilamberts. One foot-lambert is equal to $1/144\pi$ candles per square inch; brightness expressed in candles per square inch may, therefore, be reduced to foot-lamberts by multiplying by 452.

The foot-lambert is the same as the "apparent foot-candle."

(*18*) *Brightness Ratio.*—Brightness ratio is the ratio of the brightnesses of any two surfaces. When the two surfaces are adjacent, the brightness ratio is commonly called the "brightness contrast."

(*33*) *Regular or Specular Reflection.*—Regular or specular reflection is that in which the angle of reflection is equal to the angle of incidence.

(*34*) *Diffuse Reflection.*—Diffuse reflection is that in which the light is reflected in all directions.

(*35*) *Perfectly Diffuse Reflection.*—Perfectly diffuse reflection is that in which the reflected light is distributed in accordance with the cosine law, so that the reflecting surface appears equally bright from all angles of view.

The reflection from a body may be regular, diffuse, or mixed. In most practical cases there is a superposition of regular and diffuse reflection.

(*36*) *Regular Reflection Factor.*—The regular reflection factor of a surface or a body is the ratio of the regularly reflected light to the incident light.

(*37*) *Diffuse Reflection Factor.*—The diffuse reflection factor of a surface or a body is the ratio of the diffusely reflected light to the incident light.

(*38*) *Reflection Factor.*—The reflection factor of a body is the ratio of the light reflected by the body to the incident light. It is the sum of the regular and the diffuse reflection factors.

(*39*) *Diffuse Transmission.*—Diffuse transmission is that in which the transmitted light is emitted in all directions from the transmitting body.

(*40*) *Regular Transmission.*—Regular transmission is that in which the transmitted light is not diffused. In such transmission the direction of a transmitted pencil of light has a definite geometrical relation to the corresponding incident pencil. When the direction of the light is not changed, the transmission is called direct.

(*41*) *Perfectly Diffuse Transmission.*—Perfectly diffuse transmission is that in which the transmitted light is distributed in accordance with the cosine law, so that the surface of the transmitting body appears equally bright from all angles of view.

The transmission of light by a body may be regular, diffuse, or mixed. In many practical cases there is a superposition of regular and diffuse transmission.

It should be noted also that transmission factors as defined below refer to the ratio of light emerging from the body concerned to the light incident upon it. Reflections at the surfaces, as well as absorption within the body, therefore operate to reduce the transmission.

Since transmission and reflection factors depend in general on the angle of incidence, this angle should be stated. If the angle is not given, incidence is assumed to be practically normal. Transmission and reflection factors frequently vary also with the quality of light used, and consequently it should be specified or the illuminant should be stated.

(*42*) *Regular Transmission Factor.*—The regular transmission factor of a body is the ratio of the regularly transmitted light to the incident light.

(*43*) *Diffuse Transmission Factor.*—The diffuse transmission factor of a body is the ratio of the diffusely transmitted light to the incident light.

(*44*) *Transmission Factor.*—The transmission factor of a body is the ratio of the light transmitted by the body to the incident light. It is the sum of the regular and the diffuse transmission factors.

(*45*) *Absorption Factor.*—The absorption factor of a body is the ratio of the light absorbed by the body to the incident light.

The absorbed light is the difference between the incident light and the sum of the transmitted and the reflected light.

REFERENCES

[1] "The International Unit of Light," Circular No. 15, *U. S. Bureau of Standards* (1911).

[2] WALSH, J. W. T.: "Photometry," *D. Van Nostrand Co.*, New York (1926), p. 203.

[3] BOUGUER: "On the Theoretical Photometry of Diffuse Reflection," *L. Grabowski Astrophys. J.*, **39** (May, 1914), No. 4, p. 299.

[4] BERRY, E. M.: "Diffuse Reflection of Light from a Matte Surface," *J. Opt. Soc. Amer.*, **7** (Aug., 1923), No. 8, p. 627.

RÉSUMÉ OF METHODS OF DETERMINING SCREEN BRIGHTNESS AND REFLECTANCE*

W. F. LITTLE** AND A. T. WILLIAMS†

Summary.—*The importance of screen brightness as compared to auditorium brightness is referred to. Various methods of measuring and determining the brightness and reflectance of screens are reviewed. A new photoelectric illumination meter is described which should simplify the procedure of making screen measurements.*

One of the aims of the motion picture theater is to produce a screen image of sufficient brightness so that the audience can discern plainly all the details that should be seen. It is probable that no motion picture screen was ever too bright. In some cases the screen brightness may have been regarded as too great because of excessive contrasts. On the other hand, should the brightness seem uncomfortably great, that would be merely because the house lights are uncomfortably low. If the greatest brightness now in use could be doubled, the house lighting could be increased accordingly, contrasts would remain the same, and finding one's way about the auditorium would be greatly facilitated. High screen brightness, of course, is costly, and soon reaches a point beyond which it is not practicable to go.

Actual screen brightness and apparent screen brightness may differ widely, the difference depending largely upon the level of the house illumination. The latter may be at a fairly high level provided it becomes considerably reduced as one approaches the screen. Actual screen brightness depends upon:

(*1*) The illuminant in the projector
(*2*) The projection system
(*3*) The type of projector
(*4*) The film density
(*5*) The screen itself

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

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The first four items are outside the scope of this paper. The fifth may be divided into:

(*a*) The distribution characteristic, which depends upon whether the screen is of the diffusing, metallic, or the beaded type.

(*b*) The actual reflecting value of the screen material.

The diffusing screen is substantially uniform in brightness for large angles of observation from the angle of incidence, and this is substantially true whether the light be incident normally or at angles up to 25 or 30 degrees to the normal. The metallic screens are, of course, much brighter within the angle of specular reflection, but the brightness falls off rather rapidly, even at small angles from normal. The beaded type of screen has its maximal brightness in line with the incident light, the brightness decreasing also rather rapidly with departures from this angle.

Regarding the three types of screens used in the theaters, it is of interest to note that a large manufacturer of the three types reported the following percentages of sales: diffusing screens, 55 per cent; metallic screens, 30 per cent; and beaded screens, 15 per cent.

The problem of this paper is to describe the various methods that are available for determining the reflectance of the screen in service. It is assumed that whatever the type of screen used, its initial performance will have been measured in the laboratory; this paper has to do only with determining the performance in the field.

COMPARISON METHOD OF DETERMINING REFLECTANCE

Considering the diffusing screens, it is believed that the simplest procedure is the one previously proposed by the Projection Screens Committee.[1] This procedure consisted in pinning upon the screen four sheets of paper, the reflection factors of which ranged from 0.43 to 0.78; then, by observing these papers from any position in the house from which they could be clearly seen, even an inexperienced observer could compare, relatively, the brightness of the screen with respect to the papers. (The sheets of paper, bound into the JOURNAL, have reflectances of 0.43, 0.52, 0.60, and 0.78, respectively.) With this range of reflectance, the reflection factor of the screen could be readily determined.

If the screen happens to be somewhat yellow in appearance, the color difference between the screen and the paper samples may confuse the observer, so that the accuracy of the method may not be as high as desired. By squinting the eyes so as to obtain the "twilight vision" effect, the color difference largely disappears, and more accurate matches in brightness may be attained.

REFLECTION GAUGE METHOD

Another simple method of determining the reflection factor of the screen is by means of the reflection gauge (Fig. 1). This gauge as supplied by the Electrical Testing Laboratories consists of a circular disk about 3 inches in diameter. The outer part of the disk is graduated from white (approximately 88 per cent reflectance) to black

FIG. 1. Reflection gauge.

(approximately 4 per cent reflectance), and is perforated with 24 holes calibrated in approximate percentages of reflectance.

The gauge is placed upon the screen, and the brightness of the wedge matched with that of the screen showing through the perforations. The calibration of the wedge at the perforation where the match occurs gives the approximate reflection factor of the screen in per cent. If difficulty is experienced in achieving a good brightness match because of color difference, squinting the eyes will, as in the previous method, cause the difference to disappear.

Some difficulty may be experienced in matching the brightness because of the perforations in the screen. However, where small, flat patches of the screen may be observed, quite accurate determinations of reflecting power can be readily made.

The methods thus far described, of course, have the objection that they both depend to some extent upon the skill of the observer. On the other hand, high precision is not necessary. A method employing some measuring instrument, of course, is preferable. For this reason the illuminometer method has its advantages.

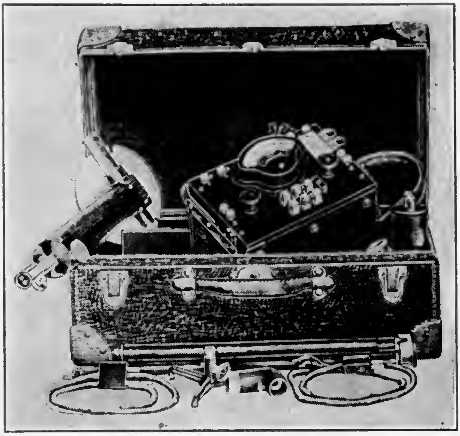

FIG. 2. Macbeth (visual) illuminometer.

ILLUMINOMETER METHODS

Two types of illuminometer are available for determining screen reflectance and brightness.

(*a*) The visual illuminometer (Fig. 2)
(*b*) The photoelectric illumination meter (Fig. 3)

(*a*) The visual illuminometer method consists in placing upon the screen a reference surface of known reflecting power and comparing it with the reflection of the screen itself. The reference surface is a specially prepared test-plate of depolished glass which is non-selective as to color reflectance. The illuminometer is pointed first at the reference surface upon the screen, and the reading is taken; then the reference surface is removed from the screen without changing any other condition, and the illuminometer read a second time. The ratio of the latter reading to the former multiplied by the reflection factor of the reference surface, is the reflection factor of the screen.

When making the measurement either the house-lights or the projector may be used as a light-source. If the house-lights are used there is a slight difference between the color of the illuminometer lamp and that of the screen, which can be corrected, if desired, with a color-filter. When the projector is used, the difference in color quality is quite considerable, and a proper color-filter should certainly be used.

The visual illuminometer method is satisfactory for testing diffusing screens, but when making reflectance measurements of either beaded or metallic screens, it is practically essential that samples of the screens be supplied at the time the screens are purchased, so that they may be stored away and carefully protected from dust and dirt. These samples should be taken from the same material as the screen itself, and are for use as reference surfaces as described above. Care should be taken not to change the aim of the illuminometer in any

FIG. 3. Photoelectric illumination meter.

way in the interim between observing first the sample and then the screen; only the sample should be removed and the screen directly behind it observed, so that the angular distribution of reflectance will remain unchanged. The direction of observation should be in the angle of reflection for the metallic screen, and as nearly as practicable in the angle of incidence for the beaded screen. It is assumed that laboratory tests have been made prior to installing the screen, and also that the samples are substantially in accordance with the condition of the screen when new. The ratio of the reflectance of the screen to that of the sample will give the depreciation of the screen.

The disadvantages of the method are the cost of the illuminometer and its maintenance and the necessity of having an observer who is skilled in reading the illuminometer.

(*b*) The photoelectric illumination meter consists of two dry-disk photoelectric cells mounted in a retainer and connected to a sensitive portable microammeter. The scales of the meter have ranges of 0–50 and 0–250 foot-candles, and 0–10 candles per square foot. The intensity of the light incident upon the screen, in foot-candles, is measured by holding the photoelectric cells upon the surface of the screen, facing the projector. The brightness of the screen is measured by holding the cells several feet away from, and facing, the screen. When brightness measurements are made, a baffle is slipped over the cells, the purpose of which is to limit the acceptance angle, which in this case was approximately 60 degrees. By making the acceptance angle of the cells 60 degrees, the width of the screen included in the measurement of average brightness would be approximately equal to the distance of the photoelectric cells from the screen.

The reflection factor (R) of the screen can then be computed by means of the formula:

$$R = \frac{\pi B}{I}$$

where B = Brightness of the screen, in candles per square foot.
I = Intensity of incident illumination upon the screen, in foot-candles.

If the brightness scale is calibrated in foot-lamberts instead of candles per square foot, then the reflection factor is merely the ratio of foot-lamberts to foot-candles. For screen measurements this unit would appear to have an advantage over candles per square foot.

When using the photoelectric illumination meter, errors will occur if the screen is not uniformly bright throughout. This is because the

TABLE I

Conversion Factors for Illumination Units

	Lux	Milliphots	Foot-Candles
Lux	1	0.1	0.092903
Milliphots	10	1	0.92903
Foot-candles	10.764	1.0764	1

Conversion Factors for Brightness Units

	Candles per sq. cm.	Candles per sq. m.	Candles per sq. in.	Candles per sq. ft.	Lamberts	Milli-Lamberts	Foot-Lamberts
Candles per sq. cm.	1	10,000	6.452	929.0	3.1416	3141.6	2919
Candles per sq. meter	0.0001	1	0.0006452	0.9290	0.00031416	0.31416	0.2919
Candles per sq. inch	0.1550	1,550	1	144	0.4869	486.9	452.4
Candles per sq. foot	0.0010764	10,764	0.006944	1	0.0003382	3.382	3.1416
Lamberts (apparent lumens per sq. cm.)	0.3183	3,183	2.054	295.7	1	1000	929.0
Millilamberts	0.0003183	3,183	0.002054	0.2957	0.001	1	0.9290
Foot-Lamberts (Equivalent foot-candles) (apparent lumens per sq. foot)	0.0003426	3,426	0.00214	0.3183	0.0010764	1.0764	1

photocell when used to measure the incident intensity, measures a relatively small spot of light; whereas when the brightness is measured, an appreciable area is included and the meter indicates the average brightness. The error may be minimized by making several measurements of the incident light, and by making the brightness measurements with the cells held fairly close to the screen so that the same area is included in both measurements.

In view of the fact that many units of illumination and brightness are in constant use, the conversion factors shown in Table I may prove convenient.[2]

This photoelectric illumination meter was first exhibited at the Fall, 1934, Meeting of the Society, by A. H. Wolferz, who designed the meter to meet the requirements for screen measurements.

REFERENCES

[1] Report of the Projection Screens Committee, *J. Soc. Mot. Pict. Eng.*, **XX** (June, 1933), No. 6, p. 510.

[2] WALSH, J.W.T.: "Photometry," *Constable & Co., Ltd.* (London), 1926, p. 470.

DISCUSSION

MR. COOK: Mr. Williams, does the sensitivity curve of the photocells used compare accurately with the visibility curve of the eye?

MR. WILLIAMS: No, it does not. The cells have a higher response in both the blue and the red ends of the spectrum, and reach a maximum at about the same wavelength at which the maximum of the eye occurs. We have a filter that will adjust the cell to the visibility curve, but the transmission of the filter and the brightness levels to be measured are so low that it is very difficult to obtain a sufficiently rugged and sensitive portable meter to measure the small current available.

We have done some work with filters that correct only the blue end of the spectrum, thus obtaining a filter having a much greater transmission and allowing the use of a more rugged microammeter because of the larger current available. Even with this partial filter the results were more consistent than could be obtained by a trained observer with the Macbeth Illuminometer.

MR. JOY: I assume that the green filter to which you refer is the one used with the Weston light-meter. Does it adjusts the sensitivity curve of the meter to that of the eye accurately? If the correction is made by the filter, does the combination of filter and meter give too small a response to be of practical use?

MR. WILLIAMS: The green filter adjusts the cell response to the visibility curve. The correction may be too great or too little at certain wavelengths, but with light having a continuous spectrum it works very well.

THE MOTION PICTURE SCREEN AS A LIGHTING PROBLEM*

M. LUCKIESH AND F. K. MOSS**

Summary.—*The motion picture on the screen is discussed as a visual task, and its lighting and that of its environs is approached in the manner recommended by the authors for all lighting problems. After choosing the proper quality of light and having a screen brightness as great as is practicable, the problem becomes chiefly one of quality of lighting or distribution of brightness in the visual fields. Various aspects of visibility and psychophysiological effects of seeing are discussed. The problem is subdivided into two parts: (1) The attainment of maximal visibility within the central field (the motion picture on the screen) without regard to the surroundings; and (2) the illumination of the surroundings in such a manner as to produce maximal comfort and minimal loss of visibility.*

The problem is unravelled from the usual entanglement of physiological optics, much of which is largely of academic interest rather than of practical importance. It is shown to be one of lighting to be guided by the same concepts, principles, and knowledge embodied in the science of seeing as are other lighting problems. Suggestions are made for practical studies of the possibilities of evolving the lighting of the motion picture screen and its environs from its present primitive stage of purely localized lighting, which is generally undesirable.

The motion picture screen is a visual task upon which the eyes and attention of the observer are focused intently for long periods. The audience consists of human seeing-machines,[1] and for them this problem of seeing, in common with all others, involves:

(*1*) The visual task
(*2*) The eyes and visual sense
(*3*) Lighting (including light)

Improvements in seeing the picture with greater ease and comfort can be achieved only through proper control of the controllable factors. The visual task is the motion picture—a changing pattern of brightness, and sometimes of color. In the case of a printed book or a newspaper, control of the visual task, which is eventually presented

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

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to the reader, is in the hands of various individuals who deal with type, halftones, paper, printing, *etc.* Analogously in the case of the motion picture, a chain of individuals is responsible for the characteristics of the task which eventually is on the screen. For the present, it is assumed that all have done their best in producing and projecting a picture. Now light and lighting become the all-important controllable factors. These factors should be best utilized for the benefit of the audience of human seeing-machines. In addition, they should be used, if possible, to compensate for deficiencies in the other factors—the visual task and the visual sense.

This lighting problem, as in the case of all others, can be divided into three major parts:

(*1*) Quality of light—color and spectral character
(*2*) Quantity of light—foot-candles and brightness
(*3*) Quality of lighting—distribution of brightness

These intricate parameters are involved in the physical characteristics of lighting in an infinite variety of combinations. Additional complexity is introduced by the usual necessity for appraising the influence of these physical variables of seeing by physiological and psychological criteria. Thus tedious biometric methods of analysis and research are necessary in laying the foundation of a science of lighting.[2]

Quality of Light.—In the case of the motion picture screen, quality of light is largely fixed by the optical requirements of projection and of the appearance of colors. Of course, the light can be modified by filters, and doubtless more could be done along this line to add refinements in the esthetic and, more broadly, psychological effects. However, from the point of view of ease and comfort of the observer, the quality of the light projected upon motion picture screens is generally satisfactory so far as available knowledge is concerned. Therefore, for the present this factor may be ignored.

Quantity of Light.—The screen brightness is obviously the result of foot-candles of projected light, densities of the photographic film, and reflection factor of the screen. Assuming that others have done their job well, the foot-candle level is largely a matter of seeing with adequate ease and comfort. The suitable level is influenced by the third factor—quality of lighting. Certainly no level readily attainable at the present time is too high for maximal comfort and ease of seeing, if the quality of lighting is suitable. Furthermore, higher levels than necessary are desirable in order that certain refinements of light and lighting may be enjoyed without undesirable decreases in visibility. Screen brightnesses vary at the present time from approximately 5 to 25 foot-lamberts. These are far below the levels indicated for easiest seeing in such cases as reading black print on white paper. Flicker is a special characteristic of the motion picture which should be minimized by every possible means.

Quality of Lighting.—For the present purpose, quality of lighting[3] is entirely a matter of distribution of brightness in the visual field of the observer. This aspect of the lighting problem under consideration is common to all lighting problems. In other words, the motion picture screen as a lighting problem is not unique; it is merely a specialized problem. Viewed in this manner, and taking into consideration the major factors that make lighting good or bad, the lighting of the motion picture screen is very primitive. It has not emerged from that era of harsh localized lighting with its dark surroundings.

Throughout the world of seeing, the art of lighting is still far behind the dictates of the science of seeing. But on almost all fronts lighting has progressed far beyond the primitive stage of purely localized lighting. It is true that an office or a library or a workshop may be found in which human seeing-machines are obliged to work under purely localized light, enduring physiological penalties such as eye-strain and fatigue, and being subjected to the depressing psychological effects of dark surroundings. But these are immediately recognized by lighting specialists as abominable conditions, and denounced as primitive and belonging to the Dark Ages before the advent of abundant, convenient, and inexpensive artificial light.

All the complex knowledge of visibility and of psychophysiological effects of seeing under various conditions are just as available for application in connection with the specific lighting problem of the motion picture screen as in other lighting problems. Naturally, this particular application of artificial light began as localized lighting, just as most other lighting practice began. Has it remained in that primitive and obviously undesirable stage of lighting development through necessity? It seems unlikely that, at the present stage of electric lighting, it is necessary for such primitive lighting to endure, at least in the larger theaters. Therefore, it appears that the important task for the lighting engineer is to determine whether there are any insurmountable obstacles that prevent the lighting of the screen and its environs from emerging from its present undesirable primitiveness. Such a study involves practically the same approach as practiced in the proper solution of most other lighting problems. Of course there is a vast underlying complexity of visibility factors and physiological and psychological effects, but if they are generally appreciated, they need not be thoroughly understood in order to investigate the problem as one of lighting practice. Furthermore, some of this complexity disappears when, and if, the lighting emerges from purely localized lighting. The complexities of rod and cone vision and of the extremes of retinal adaptation are involved in the present condition of a bright screen surrounded by "darkness." Some of these disappear or are greatly reduced in importance.

If the lighting of the motion picture screen and its environs must remain as it is, the various psychophysiological complexities are merely of academic interest. If reasonable advance toward good lighting can be achieved, the complexity diminishes and the lighting engineer needs only to apply the dictates of the science of seeing to his experiments and practice.

General Considerations.—The fundamental factors of the visual task that determine its visibility are (*1*) size of details to be seen, (*2*) contrast in brightness (and color) with their background or immediate surroundings, (*3*) brightness level (both absolute and relative), and (*4*) time available for seeing. The relationships of these factors[4] have been fully established, and form the basis of visibility. However, other factors of the surroundings are modifying influences. All these primary and secondary factors are more or less controllable. The best compromise is the best solution.

Eyesight, or the visual sense, is another factor in the chain. It is controllable only to the extent that aids such as glasses may be directly applied. However, as revealed by the science of seeing, other controllable factors can, to some extent, compensate for deficiencies in uncontrollable factors. Thus, more light and better lighting can compensate somewhat for subnormal vision. Lighting should eventually include "factors of safety" so that it is ideal at least for "average subnormal vision" instead of merely ideal for average "normal" vision. Besides, it should be noted that the ability to see brightness differences is not indicated by the usual eye tests.

Inevitably, considerations of controllable factors in seeing lead to light and lighting. Our present problem is largely a matter of quality of lighting, after adequate light of acceptable color and spectral character is available on the screen and the flicker has been minimized. Quality of lighting may be defined as a function of the brightness characteristics of certain unique portions of the visual field. These brightnesses are critical factors in both the absolute and relative sense. Although quality of lighting is thus defined in general mathematical terms for reasons of simplicity and clearness, it is not implied that this complex phase of lighting is at present completely reducible to a basis expressible by formulas. In fact, an adequate and rational terminology in this field has not been formulated. Many of the terms now in use are merely descriptive of the effects produced by *extreme* conditions of quality of lighting. *Glare* may be cited as an outstanding example. Other terms from physiological optics, such as adaptation, induction, and illusion, are useful as definite and accepted descriptions of phenomena related to the quality of lighting. The *millilambert, foot-lambert,* and the *photon* are fundamental units; the *foot-candle* is not. Throughout lighting language and practice the prominence of the engineering point of view and the general absence of the psychophysiological point of view is obvious. This status must be reversed if lighting is to be practiced for the purpose of seeing and of service to human seeing-machines. The light-source, the lighting equipment, and the lighting installation become merely engineering links in the chain, just as conduits and wiring are. They are merely means to an end—to see efficiently, effectively, safely, comfortably; in other words, to see with the least waste of human resources.

Although the science of seeing is far from complete, it has adequately revealed the major aspects and principles upon which ideal lighting depends. Such knowledge combined with everyday experience makes it possible for the lighting engineer to proceed to the practical solution of his problem with considerable assurance and clarity of procedure and objective. In the case of the lighting problem connected with the motion picture screen, it is necessary first to consider this a *lighting* problem, and to direct the thought along conventional lines of lighting. Usually it has been considered quite apart. This is an untenable attitude, which has entangled the considerations in the complexity of psychophysiological optics. To escape this entanglement is the first step toward solution by practical experimentation. A practical example should be helpful at this point.

The motion picture screen does not differ fundamentally from other common tasks requiring prolonged attention, such as reading a book. Let us examine briefly the case of reading. Immediately two portions of the visual field must be considered. One is the *central* or work-field, which is the printed page. The other is the *surroundings* or peripheral field. Certainly the printed page must be bright in order to read with ease and comfort. There are two brightness levels of fundamental importance. One is the low level for *barely seeing*, which is obvious to the observer. The other is the high level for *easiest seeing*.[5] This level is not obvious to the observer, and is being established by complex researches in the far-reaching psycho-physiological effects of seeing. Certainly it is of a different order of magnitude than the level for barely seeing. In the case of reading ordinary black print on white paper, one brightness level is a fraction of a foot-lambert or that produced by a fraction of a foot-candle on white paper. The other brightness level is several hundred foot-lamberts, or that produced by several hundred foot-candles on white paper. Any level between these is a compromise. It has meaning only when based upon a certain degree of visibility or ease of seeing.

From a psychological point of view the printed page should be the brightest area in the visual field. The brightness of the surroundings should not be sufficient to distract attention. On the other hand, they should not be extremely dark because of physiological effects such as eye-strain and eye fatigue. Recently we have proved that certain eye muscles are more fatigued under the condition of dark surroundings than when some general lighting is available as well as purely localized lighting. Apparently, very dark surroundings are just as distracting as surroundings of brightnesses comparable to the visual task. At any rate a compromise brightness-contrast for the screen and the environs is theoretically desirable.

Let us examine the other extreme condition found in lighting practice—a large room illuminated by a system of indirect lighting. Now, the ceiling is the brightest area in the visual field. It is much brighter than the printed page of a book one reads. It not only causes distraction but reduces visibility of the printed page, because there is no escape from this relatively high brightness of considerable angular extent. There can be little doubt that the same visual, physiological, and psychological effects are produced in this case as in the case of dark surroundings and bright printed page, but in different proportions, and even of different magnitudes. Certainly, in general, the condition of dark surroundings is the less desirable of the two conditions. Both these extremes have been mentioned not only as a background for the discussion but to illustrate that compromises are commonly desirable or necessary in lighting as in other practical matters.

Now imagine the printed pages of the book to be held vertically at the usual reading distance. In visual size it compares with that of the motion picture screen for most of the audience in a motion picture theater. Would anyone, knowing what good seeing conditions are, be satisfied to read for an hour or two with the surroundings as dark as they are in the theater? Would he even want to look at pictures in the book for an hour or two?

Basic Considerations.—Recently we summarized the concepts, principles, and knowledge of visibility[6] and psychophysiological effects of seeing from the point of view of quality of lighting.[3] This summary is applicable to the present problem. Therefore, only glimpses of the more pertinent practical considerations will be touched upon here.

In appraising the quality of lighting in the central field the eventual end-products—psychophysiological effects of seeing—are of final importance. For this reason initial and momentary casual appraisal may not reveal the effects of seeing under the given conditions for an hour or two. Notwithstanding this, the visibility of objects of regard must be a primary criterion of lighting for seeing, and, therefore, the establishment of correlations between visibility and time-effects of seeing is an important matter. Much progress has been made in this direction through researches in seeing as an activity of human seeing-machines.

It appears axiomatic that the conservation of vision and other human resources expendable in the process of seeing must depend largely upon the *positive* contributions of the lighting within the central field where critical visual tasks are performed. The influences of the lighting of the surrounding field are both positive and negative. Certainly the latter should be minimized or entirely eliminated if possible. Thus two distinct steps in the design of lighting are suggested:

(*1*) The attainment of maximal visibility within the central field without regard to the surroundings.

(*2*) The lighting of the surroundings in such a manner as to produce maximal comfort and ease, and minimal loss of visibility in the central field.

The important positive contribution of the lighting of the surroundings is the creation of conditions that will provide maximal visual and mental relaxation, minimize eye-strain and fatigue without causing undue distraction from the picture, and promote safety. This means a proper balance or compromise of these factors. In this connection the angular size of the central field is important.

The visual sensory processes have evolved to mediate extreme variations in brightness stimuli by changes in pupillary aperture, retinal adaptation, and, perhaps, by neurological adaptation of the higher brain centers. However, many of the complexities in lighting practice are introduced by the inability of the visual sense to compensate adequately, within the time available, for changes in brightness as the eyes are directed to various areas of the visual field. If the visual sense could become adapted instantly and completely, there would be no deleterious effects of brightness changes and contrasts. Some of these effects are noticeable because of their magnitude. However, all degrees are present in lighting. Most of them become noticeable only by careful measurement.[7] Many of these temporal characteristics are of fundamental importance in lighting practice. Their significance in seeing depends upon:

(*1*) The differences in absolute brightness
(*2*) The rate and frequency of the changes in brightness
(*3*) The area and position of the stimuli
(*4*) The criticalness of the visual tasks to be performed

Many of these phenomena have been investigated qualitatively, but only recently have researches in seeing begun to adopt experimental conditions that are comparable with those in practice. Some of those phenomena of interest in the motion picture theater will be touched upon briefly.

Everyone is familiar with the temporary blindness experienced upon entering a comparatively dark theater. Due to the enormous change in brightness the pupillary mechanism is comparatively ineffectual as a compensating device. Most of the compensation is attained through retinal adaptation. The inconvenience and potential danger of this temporary blindness would cease to be serious if adequate general lighting could be added without unduly diminishing the visibility and satisfactoriness of the picture on the screen. The flicker on the screen is also apparent to everyone. Of course, every resource of science and invention should be utilized to reduce or eliminate this. The noticeability of flicker on the screen decreases with increase in frequency and increases with increase in screen brightness. It would also decrease with increase in extraneous light on the screen. Of course, this would also diminish the contrasts in the picture. However, small compromises of this nature may be possible and even practicable if the brightness of the projected picture is adequate.

The annoying contrast between the screen and surroundings has been mentioned several times. We have found by actual measurement that certain eye muscles are more fatigued while reading a book amid dark surroundings accompanying purely localized lighting than when there is some general lighting in the room. When there was very low brightness of surroundings compared with that of the printed page, this fatigue was measurably reduced. It should be pointed out that the reading involved near-vision. Viewing a motion picture involves only distant-vision. This is one redeeming feature of the motion picture as a visual task. It is possible that the fatigue of the eye-muscles, due to dark surroundings, is not as great for this task of distant-vision as for reading a book. Sources, even mildly glaring, in the surrounding field produce measurable physiological effects. The common use of highly colored light appears inadvisable in the surrounding field for the same psychophysiological reason as darkness and glaring sources.

The criticalness of the motion picture as a visual task is less than that of reading a book. One is not interested in details near the threshold in size. Visual acuity is of less importance than discrimination of brightness and brightness contrast. Much of the story is told in words, gestures, facial expressions, and action. The visual task is not critical, but eyes and attention are focused steadily and with brief respites.

It is known that sensibility to brightness difference is greatest when the surroundings are approximately of the same brightness level.[8] If fixation is maintained in the central field, apparently the surroundings influence visibility and visual efficiency when the central field subtends a solid angle less than 30 degrees. The angular extent of motion picture screens varies from approximately 5 degrees for observers in the rear seats of some theaters to 50 degrees for persons in the front seats of other theaters. Wherever it is less than 30 degrees the dark surroundings reduce visibility and visual efficiency even when the eyes are fixated upon the center of the screen. The dark surroundings are also distracting and cause greater fatigue of the eye-muscles than brighter surroundings. In addition, when eyes are directed to these dark surroundings the entire adaptive mechanism and visual process are affected. A moderately low brightness of the surroundings would be beneficial in many ways.

Pupillary phenomena of much interest and significance in many lighting conditions are of no practical significance in viewing the motion picture. Although fixation may shift rapidly among areas of various brightnesses, the relatively slow rate of pupillary dilation as compared with contraction prevents correspondingly rapid muscular fluctuations which conceivably might result in ocular discomfort.

It is not unusual to experience deleterious effects under certain seeing conditions which, for *a priori* reasons, are not necessarily describable as extreme. In such cases, the influences of improper lighting upon easy and comfortable seeing may be fundamentally of a psychological character even though they produce physiological effects. They may even reduce visibility, because seeing involves the vagaries and reactions of *human* seeing-machines. The factors of attention and distraction should be recognized in lighting, notwithstanding the general lack of significance of such phenomena to engineers untrained in the realm of psychology. These are powerful forces in the efficiency and comfort of human beings and in their reactions toward lighting. In this connection it should be noted that darkness is just as definitely a sensation as brightness is. Why should it not produce the same kind of psychological effects as brightness does?

Subjective phenomena that arise from voluntary attention to a critical visual task may be appreciated through the performance of a few simple experiments. Brightnesses within the peripheral field which do not seem extreme during casual seeing may be quite annoying when critical seeing is attempted. For example, in the casual viewing of a landscape during the daytime, the brightness of the sky may not seem unduly high. However, if reading is done with the same area of sky in the same position in the peripheral visual field, its brightness may become very annoying, even to the point of discomfort. We must consider darkness in the surroundings in the same manner.

The reflex that causes the eyes to turn and fixate an extra-foveal stimulus, as well as the exactness of the fixation, are functions of the visibility of objects in the visual field. High brightness contrasts or objects in motion encourage attention and fixation, and, therefore, are undesirable. Obviously, dark surroundings represent the ultimate in the suppression of details in the surroundings or peripheral field. But undesirable effects of dark surroundings, such as eye-strain and fatigue, create the necessity for considerable adaptation which conflicts with the advantages of dark surroundings. This is true also of the psychological reality of darkness. All experimental evidence indicates that peripheral brightnesses greater than those of the central field are definitely undesirable. Therefore, it must be concluded that brightnesses lower than those of the primary visual task or central field are desirable. These conclusions are based upon the assumption that critical seeing for long periods is the predominant characteristic of the visual activity. It should be obvious that a casual appraisal of lighting conditions is of little value. It neither involves this criterion nor any dependable measurements. The science of seeing has adequately proved the inadequacy of casual judgment or, for that matter, any judgment unaided by measurements.

Certainly *balance* of general lighting and localized lighting is important everywhere that this combination is used. In fact, *balance* of the brightnesses of the central and surrounding field is actually a valuable tool.

Suggestions.—As stated at the beginning, the motion picture is a visual task, and is a lighting problem involving the same fundamentals as other lighting problems. There is nothing mysterious about it, and there is no more reason for the lighting engineer to become entangled in a maze of physiological optics than in dealing with most problems of lighting practice. Either the lighting must remain in its present primitive stage or it should evolve into better lighting. The latter means little more than adding as much brightness to the immediate environs of the screen as is practicable without seriously reducing the visibility and satisfactoriness of the picture. However, there is no valid reason why the picture should receive all the attention and the audience little or none. Actually, it is not relatively more important than any other visual task that is daily performed by millions of persons for prolonged periods. Of course, the audience may not complain of present primitive and penalizing lighting conditions. It accepts what it is used to just as it has done in other lighting fields. Besides, we now know that eyes know no more about lighting requirements and the hidden and remote effects of seeing than the stomach knows about food requirements, refinements, and effects.

First, we would suggest that experiments be made by surrounding the screen with uniform brightnesses of different magnitudes less than the screen brightness. In Fig. 1 this is described as the intermediate field, *I*. Preferably, this surface, which may be a plain or a draped curtain of moderately high reflection factor, should be behind the plane of the curtain, so as to reflect no light directly upon the picture screen. This intermediate field may well be white or nearly so. The peripheral field, *P*, may be the front wall surrounding the stage opening and also the side walls. *P* would be considerably lower in brightness than the screen, and *I* would be lower in brightness than the screen. It is unnecessary to estimate these brightnesses because the experiments should be designed to determine those that seem best, and also how bright they could be without noticeably "diluting" the picture by extraneous light. Certainly, low brightnesses for *I* and *P* are better for easy, comfortable, and safe seeing than "darkness," which is so prevalent now. Striking contrasts in color should be avoided in the initial experiments, although colored light for the environs might eventually be studied. The value of the atmospheric effects of colored light should be weighed against the disadvantages of distraction due to conspicuous color contrast. Experiments might well be made to determine how much superposed brightness a picture will "stand" by directing light upon it. Such studies might include even colored light, for the purpose of ascertaining the possibilities of esthetic and other psychological effects.

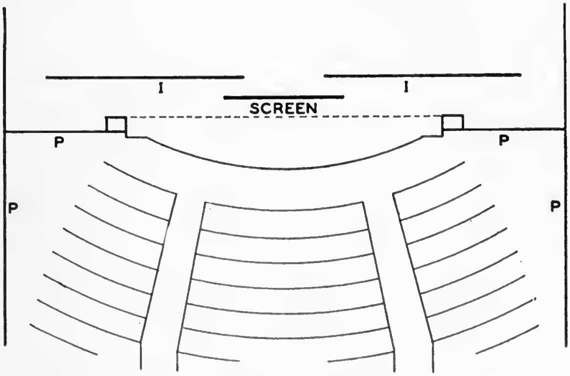

FIG. 1. Diagram showing the screen surrounded by a luminous intermediate field (*I*) and luminous peripheral field (*P*) consisting of front and side walls. In theaters with low ceilings, the peripheral field would include also the ceiling.

By making all measurements directly in terms of brightness the results become universally applicable and interpretable. Effects upon the reduction of the noticeability of flicker can be recorded. The observers should actually view the motion picture for a sufficient period. No doubt there will be differences of opinion, because the results are qualitative, but surely some idea can be obtained of the possibility of improving the present primitive lighting. Our ophthalmic ergograph[9] could readily be used to determine the fatigue of the extrinsic eye-muscles before and after viewing the picture for a certain period under a given lighting condition. We have used it extensively with marked success in studying effects of light and lighting.

Next it may be advisable to measure the visibility of objects on the screen under different brightnesses of surroundings I and P, and upon addition of certain low brightnesses superposed upon the screen. For this purpose we would suggest a test-object consisting of a lantern slide or positive transparency of our Visibility Indicator[10] extending over the entire area of the screen. This consists of a page of printed matter superposed on a brightness gradient varying from white at the top to black at the bottom. This can be made as a photographic positive transparency. The size or sizes of type can be selected so as to be readable from any seat in the theater. The lines can be numbered consecutively from top to bottom. Each of a group of observers can read the lines, beginning at the top, and a record made of the number of the lowest readable line. In this manner the effect upon visibility of the various lighting effects can be determined.

Certainly in such a manner the practicability of elevating the lighting of the motion picture screen from its present stage can be ascertained. Also, some idea of the sacrifice of visibility for better lighting can be determined. Then if the actual motion picture still appears satisfactory, the major factors of the problem are solved. If and when this is accomplished, any secondary aspects of physiologic optics can be studied. However, with better lighting it will be found that many of these other problems will disappear, or become matters of little practical interest. If better lighting is impracticable and the lighting must remain in the present primitive stage, there seems to be little point to studying these phases of physiological optics. There is little gained in the world of practice in knowing *why*, if nothing can be done about it. That is territory to be explored by the research laboratory.

We could readily make the visibility test-objects because we have developed technic for producing photographic gradients. We shall be glad to elaborate upon the suggested experimental attack and to discuss many possible modifications and substitutes with any individuals or Committees contemplating such a research.

REFERENCES

[1] LUCKIESH, M., AND MOSS, F. K.: "The Human Seeing-Machine," *J. Frank. Inst.*, **215** (June, 1933), No. 6, p. 629.

[2] LUCKIESH, M., AND MOSS, F. K.: "The New Science of Lighting," *Trans. I. E. S.*, **29** (Sept., 1934), No. 8, p. 641.

[3] LUCKIESH, M., AND MOSS, F. K.: "Quality of Lighting," *Trans. I. E. S.*, **30** (July, 1935), No. 7, p. 1.

[4] LUCKIESH, M., AND MOSS, F. K.: "Seeing—A Partnership of Lighting and Vision," *Williams & Wilkins Co.*, Baltimore (1931).

[5] LUCKIESH, M., AND MOSS, F. K.: "Reflex Effects from Critical Seeing," *Amer. J. Ophthal.*, **18** (June, 1935), No. 6, p. 527.

[6] LUCKIESH, M., AND MOSS, F. K.: "Visibility—Its Measurement and Significance in Seeing," *J. Frank Inst.*, **220** (Oct., 1935), No. 4, p. 431.

[7] LUCKIESH, M., AND MOSS, F. K.: "The Rate of Visual Work on Alternating Fields of Different Brightness," *J. Frank. Inst.*, **200** (Dec., 1925), p. 731.

[8] COBB, P. W., AND MOSS, F. K.: "The Effect of Dark Surroundings on Foveal Vision," *J. Frank. Inst.*, **206** (Dec., 1928), No. 6, p. 827.

[9] LUCKIESH, M., AND MOSS, F. K.: "Fatigue of Convergence Induced by Reading as a Function of Illumination Intensity," *Amer. J. Ophthal.*, **18** (April, 1933), No. 7, p. 319.

[10] LUCKIESH, M., AND MOSS, F. K.: "The Applied Science of Seeing," *Trans. I. E. S.*, **28** (Dec., 1933), No. 10, p. 842.

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SPRING 1936 CONVENTION, CHICAGO, ILL.

As this issue of the JOURNAL goes to press while the Convention of the Society at the Edgewater Beach Hotel, Chicago, is in progress, it will not be possible to describe the highlights of the Convention until the next issue. The tentative papers program and abstracts of the presentations were published in the April issue of the JOURNAL.

GREAT BRITAIN ADOPTS S. M. P. E. 16-MM. STANDARDS

(*Press release of the British Standards Institution*)

For some time past the development in this country of 16-mm. sound-films, both for amateur productions and for educational and propaganda purposes, has been severely handicapped through the absence of a national agreement as to the position on the film of the sound-track, and also as to which side the emulsion should be.

There have been two different standards available in this country during the past two years, differing fundamentally in that both the emulsion and the sound-track are in opposite positions, so that the films are not interchangeable. If this situation had been allowed to continue both users and producers would have been severely handicapped.

However, those directly interested in the production of apparatus and in making film libraries were unanimously of the opinion that a single standard was essential, but they could not reach agreement among themselves as to which standard to adopt. In a very public-spirited manner, they all agreed to accept the ruling of an independent arbitrator to be appointed by the British Standards Institution, to whom they referred the question.

The arbitration which was recently held in the Middlesex Guildhall (London) to determine what is to be the British Standard for this purpose is, therefore, a matter of considerable public interest. Lord Riverdale kindly undertook to act as Arbitrator.

The two rival standards correspond closely with the S. M. P. E. (American) Standard on the one hand, and the DIN (German) on the other.

The case of those supporting the DIN standard was presented at the arbitration by Mr. Bruce-Woolfe, of Gaumont British Equipments, while the case on behalf of those supporting the S. M. P. E. standard was put forward by Mr. F. A. Hoare, of the Western Electric Co., Ltd. Lord Riverdale's decisions were as follows:

(1) At the request of all the parties concerned I agreed to act as Arbitrator in regard to the standard which should be adopted as the British Standard.

(2) Accordingly, I attended at the Middlesex Guildhall on Wednesday, 26th of February, to hear evidence. In addition, I have carefully examined all the written material which has been furnished to me of every kind.

(3) My award is that the S. M. P. E. standard shall be adopted as the British Standard.

(4) Quite apart from my award, and not affecting it in any way, I venture to suggest that the parties might get together and endeavor to find some means of minimizing the inconvenience and possibly giving a little time for those who have been working on any other standard than the S. M. P. E. to make the change-over.

This decision, which, it must, of course, be remembered, refers *only* to the 16-mm. sound-film, will shortly be implemented by the issue of an appropriate British Standard Specification. In the meantime the constituent parts of the British Empire have been consulted and it is anticipated that they will accept this decision, Australia having already indicated her willingness to do so.

The decision means that throughout the English-speaking world educational films will be interchangeable.

In regard to paragraph 4 above, it was fully recognized that whichever standard was adopted, it must necessarily result in some inconvenience to those who have to make the change; but that the advantages of a single standard will enormously outweigh any temporary inconvenience or loss.

STANDARDS COMMITTEE

At a meeting held at the General Office of the Society on April 9th, revised drawings for the Standards Booklet, prepared by Mr. George Friedl, Jr., were considered by the Committee, and much progress was made toward the revision of the Booklet. Although there will be no important change in the context, the form of presentation of the various standards will probably be altered considerably in the interest of clearness and simplicity.

SECTIONAL COMMITTEE

The first meeting of Sub-Committee No. 3—Acoustical, of the Sectional Committee on Motion Pictures, ASA, was held at the office of the Society on April 16th. The purpose of the meeting was to outline the plans of the Committee and to investigate possible national standards relating to sound in motion pictures. The personnel of the Committee is as follows:

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In addition, since the publication of the list of members of the Society in the April issue of the JOURNAL, the following applicants have been admitted by vote of the Board of Governors to the Active grade:

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CONTENTS

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See p. 697 for Technical Committees

CONDENSERS FOR 16-MM. OPTICAL SYSTEMS*

G. MILI** AND A. A. COOK†

Summary.—*The demand for higher levels of illumination in 16-mm. projection has led to an investigation of the possibilities of improving the efficiency of the optical systems involved. An analysis of spherical and aspheric condensers of various designs is presented to show the best possible combination with an f/1.65 projection lens and the present high-intensity biplane filament type of lamp.*

INTRODUCTION

The increasing interest in 16-mm. film equipment for non-theatrical projection, particularly in the fields of industry and education where the illumination requirements are relatively high, makes especially timely a study of the optics involved in 16-mm. projection. Since the dimensions of the film-gate are standardized and projection lenses of larger aperture than *f*/1.65 are not at present available, the possibilities for higher optical efficiency are limited to improvements in light-source brilliance and the choice of high-efficiency condensers. The development of the biplane filament tungsten lamp[1] was a step of major importance in the attainment of greater light-source uniformity and higher brilliance, and in the present state of the lamp manufacturer's art, further improvements are highly improbable. Any further increase in brilliance could be attained only by raising the filament temperature, which would mean reduced lamp life. Projection lamps are now designed for 50 and 25 hours of life, but with the growing acceptance of even shorter-life lamps for special purposes, such as the 2-hour photoflood lamp for photography, it is quite possible that 10-hour lamps, or over-voltage operation of the present 25-hour lamps, may well afford an economical solution where maximum illumination is required for relatively short periods of time.

While one-inch spherical condensers have been almost universally used until lately, a trend toward the use of larger condensers, par-

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** Westinghouse Lamp Co., Bloomfield, N. J.

† Bausch & Lomb Optical Co., Rochester, N. Y.

ticularly of the aspheric type, is now evident. In practice, condensers have been designed not so much for maximum optical efficiency as to conform to the space limitations imposed by the mechanics of the projector. This procedure has often handicapped optical performance, higher levels of screen illumination having been attained merely by the introduction of higher-wattage lamps rather than by the improvement of optical efficiency. To deal with the problem of determining the best possible optical performance in 16-mm. projection systems through an analysis of spherical and aspheric condensers of various diameters and magnifications is the object of this study.

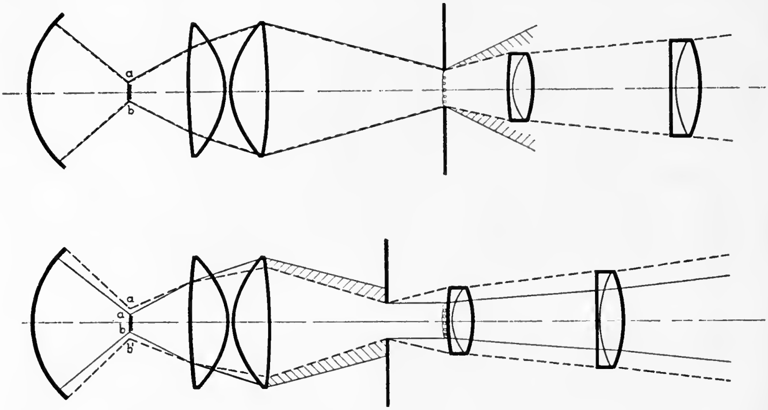

Fig. 1. Diagrams of 16-mm. optical system, tracing the paths of the limiting rays for two positions of the film-gate with respect to the light-source image.

THEORETICAL CONSIDERATIONS

On the basis of theoretical optics the highest efficiency would be attained if the film-gate were placed in the plane of the light-source image formed by the condenser, the magnification of the condenser being such as to fill the whole field of view with the smallest possible source. Since the available light-sources are not perfectly uniform, to obtain even illumination it is necessary to place the film-gate at some intermediate point between the condenser and the plane of the light-source image. The effect of this displacement of the film-gate is two-fold: first, part of the light emerging from the condenser will be screened off at the film-gate; and, second, it has been found, through back-testing, that the dimensions of the light-source required to fill the exit pupil of the projection lens will increase. This is shown clearly in the two diagrams of the optical system given in Fig. 1. In the top diagram the film-gate is in the plane of the light-source image; in the lower diagram the gate is so placed that the light-source image falls at the back surface of the rear element of the projection lens. The broken lines indicate the path of the limiting rays emerging from the exit pupil of the system, the projection lens. The full lines trace the marginal rays of the light cone emerging from the condenser. *ab* corresponds to the light-source dimension required for filling the field of view with the film-gate in the first position; *a′b′* represents the light-source dimension required for filling the exit pupil of the system with the gate in the second position. It may be timely to point out that if the available source is as large as, or larger than, *a′b′*, the screen illumination will be the same with the film-gate at both positions. If, however, the source is smaller than *a′b′*, the screen illumination will be greater with the gate located in the plane of the light-source image.

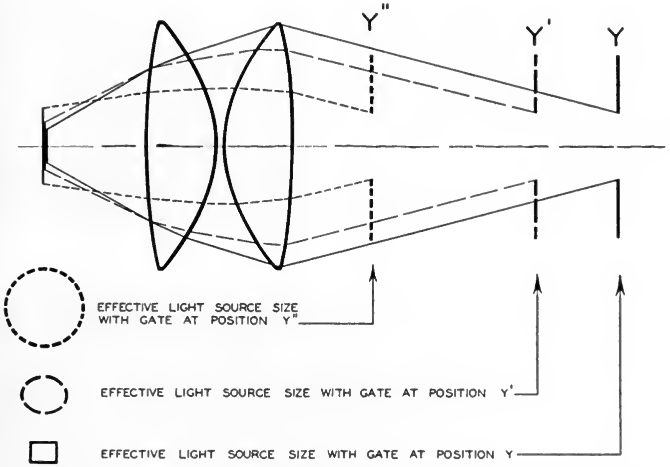

FIG. 2. Change in effective light-source shape and dimensions caused by film-gate movement. *Y* represents a position of the gate coincident with the light-source image.

The increase in the size of the light-source required for filling the exit pupil as the film-gate is brought closer to the condenser is demonstrated in Fig. 2. The paths of the limiting rays and the dimensions of the light-source required for filling the objective lens are indicated

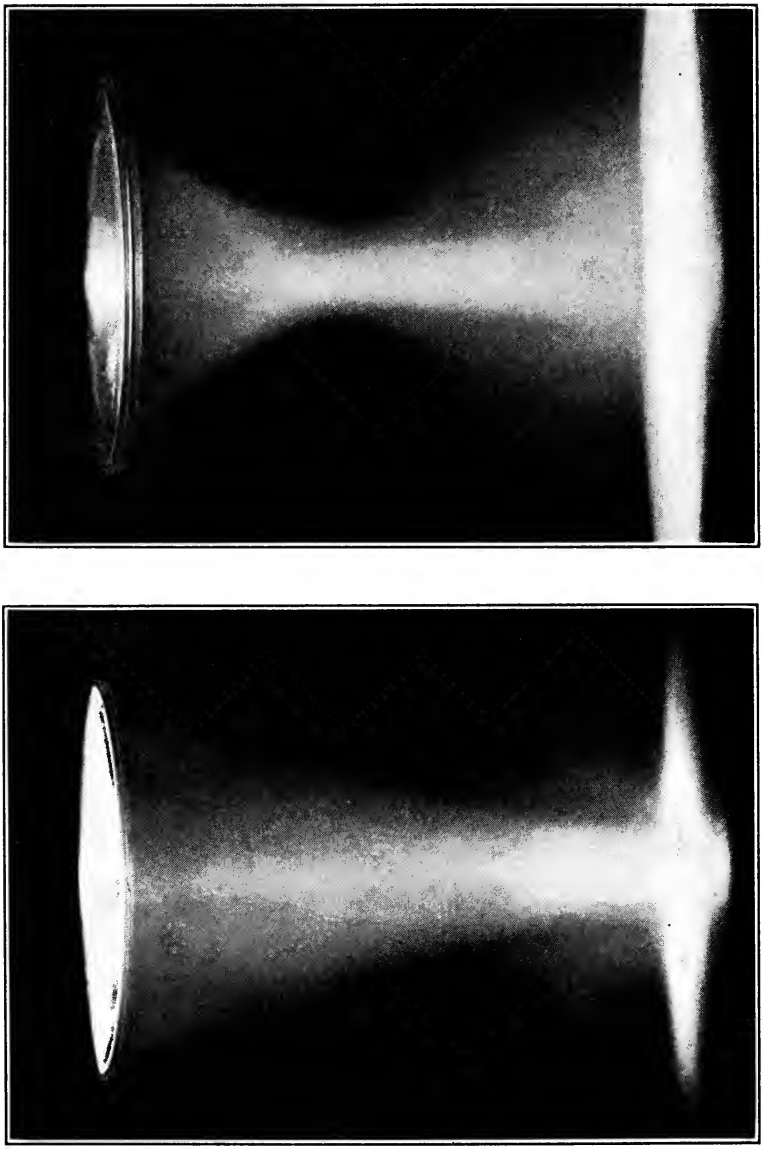

FIG. 3. (*Top*) Photograph showing the large divergence and degree of non-uniformity of the light-cone emerging from spherical condensers; (*bottom*) the improved uniformity and higher concentration attainable with aspheric condensers.

at three positions, *Y*, *Y′*, and *Y″*. *Y* shows the film-gate at the plane of the light-source image. From the drawing it can readily be seen that the effective light-source changes not only in size but also in shape. With the film-gate in the plane of the light-source image, the shape of the effective light-source duplicates the shape of the film-gate; that is, a rectangle of dimensions equal to the dimensions of the gate divided by the magnification factor of the condensers. As the film-gate is moved nearer and nearer the condenser, the effective light-source assumes first an oval shape, and finally a circular shape of increasing size.

Thus far in the discussion no mention has been made of the effects of the spherical and chromatic aberrations of the condenser upon the optical performance. For the purpose of this study chromatic aberration is of little significance and may be disregarded.[2] Much more important, however, is spherical aberration. A condenser with spherical aberration will produce a cone of light with the cross-section sufficiently uniform for projection only in a plane near the lens surface. Furthermore, the angle of the light-rays emerging from the outer zones of the condenser is much greater than that at which the rays emerge from the central zones, thereby creating a large circle of spilled light around the image proper, with an attendant loss in efficiency. To minimize both these deficiencies, condensers with an aspheric surface have been designed. The improved uniformity and higher degree of concentration of the light-cone emerging from aspheric condensers as compared to that emerging from spherical is shown in the photographs in Fig. 3.

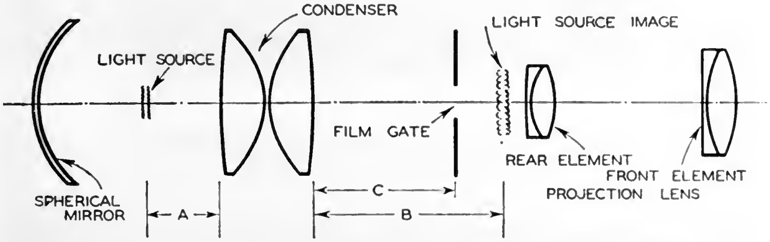

FIG. 4. Optical elements of 16-mm. film projection system.

TEST PROCEDURE

A series of tests was run with both spherical and aspheric condensers subtending essentially the same pick-up angle with respect to

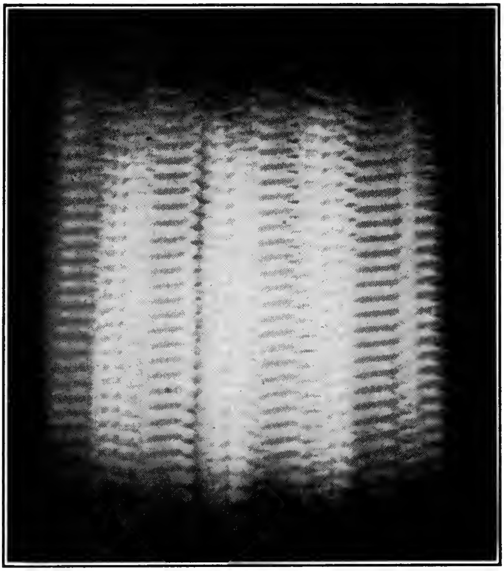

FIG. 5. The size of the light-source used for test is approximately 9 × 9 mm.

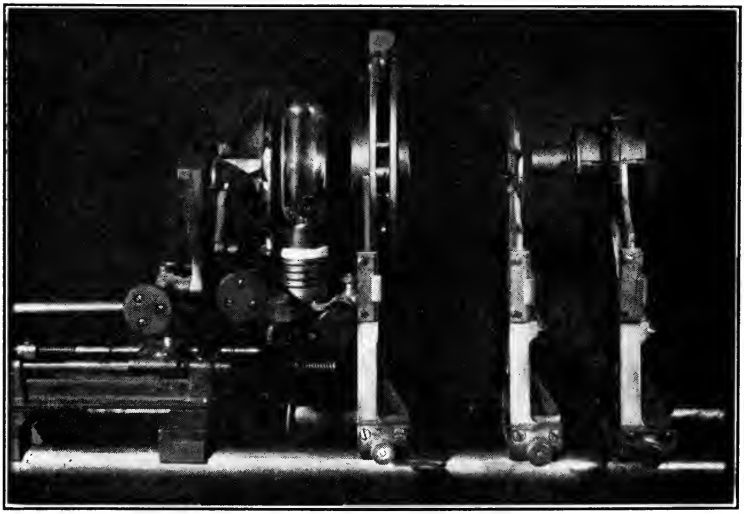

FIG. 6. Optical bench set-up.

the light-source, but varying in dimensions, focal length, and magnification. Table I contains data pertaining to spherical and aspheric condensers of three different diameters (26, 45, and 65 mm.) but equal magnification (2.08X), as well as data for aspheric condensers of equal diameter (45 mm.) but three different magnifications (1.39X, 2.08X, and 3.12X). The various parts of the optical system and their relative positions are shown in Fig. 4. A 500-watt, 100-volt biplane filament projection lamp with a spherical mirror was used as a light-source. Fig. 5 is a photograph of the source, which measures approximately 9 by 9 mm. As is well known, the mirror improves the source uniformity by filling the openings between filament coil turns, and increases the average brilliance.

TABLE I

Condenser Data

Curvature	Diameter (Mm.)	E. F. (Mm.)	Magnification X	A (Mm.)	B (Mm.)
Spherical	26	12.9	2.08	11.1	31.6
	45	23.0	2.08	21.7	58.5
	65	33.4	2.08	32.3	85.7
Aspheric	26	12.5	2.08	13.0	33.0
	45	22.6	2.08	23.5	59.5
	65	33.2	2.08	34.5	87.5
Aspheric	45	23.1	1.39	22.4	44.7
	45	22.6	2.08	23.5	59.5
	45	23.1	3.12	20.2	77.0

Measurements were made of the total light output and of the brightness at the center and the four corners of the screen, with the film-gate varying from the theoretical plane of the light-source image to the point where the gate was located against the condenser surface. This procedure was followed for each condenser set. Fig. 6 illustrates the method of mounting the various elements of the system upon the optical bench. Relative screen lumen readings were obtained by means of a 30-inch integrator with a circular glass window, shown in Fig. 7. The gate, which represents optically the field of view, was focused at a distance of 7 feet, the screen being approximately 16 inches wide and 12 inches high. For measurements of screen brightness a Weston photronic cell illumination meter was used, as indicated in Fig. 8, the measuring area being limited to the surface of one cell, a circle $1^1/_2$ inches in diameter.

RESULTS

In Fig. 9 are given curves showing the variation in the *screen light output* as well as the *corner-to-center screen brightness ratio* for spherical condensers of 2.08X magnification with the gate position varied from the plane of the filament image to the condenser surface. The distance between the condensers and the plane of the light-source image (dimension B, Fig. 4) is different for each condenser set, and depends entirely upon the diameter and the magnification. In order to facilitate comparison, in plotting the curves this distance has been rendered equal to unity in all cases. Thus with the 26-mm. condenser set the film-gate must be moved 25 millimeters from the plane of the light-source image, and with the 65-mm. condenser, 45 millimeters, before the screen is free from striations. The former movement covers fully 0.8 of the total available range, whereas the latter movement covers only 0.54.

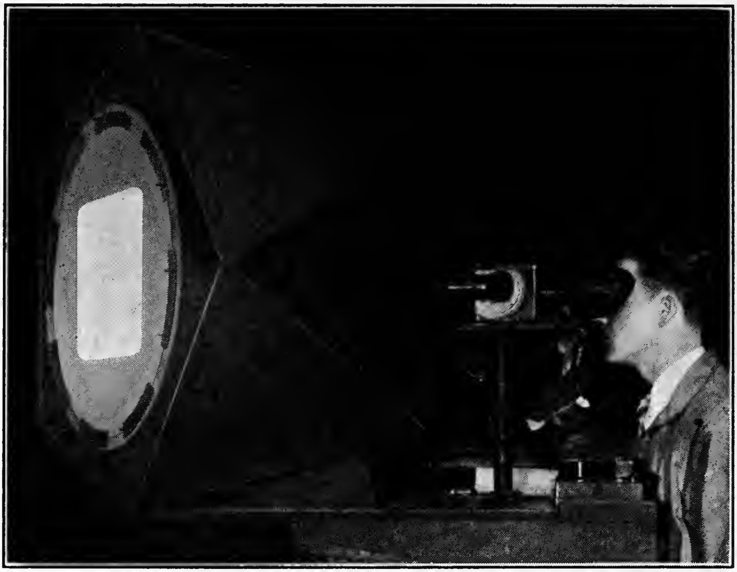

FIG. 7. Integrating photometer for total screen lumen measurements.

The heavy-line portion of the screen light output curves represents the region in which the screen appearance is free from light-source images and striations. In Fig. 10 are similar curves for the aspheric

FIG. 8. Measurements of screen brightness with Weston photronic cell illumination meter.

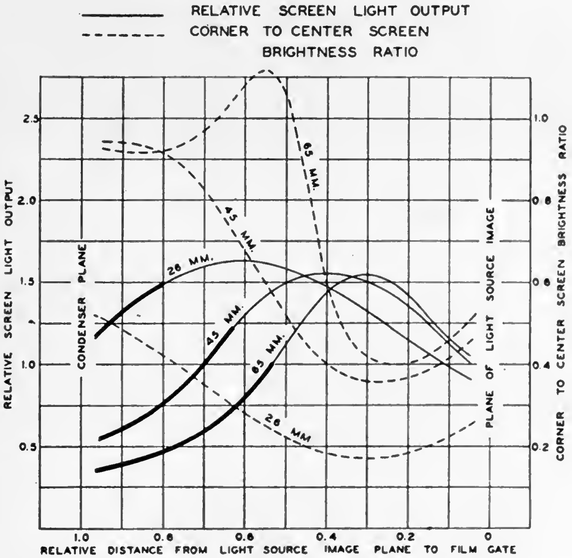

FIG. 9. Photometric data for spherical condensers of 2.08X magnification (26, 45, and 65 mm. in diameter).

condensers of the same magnification, *viz.*, 2.08*X*. It may readily be seen that the light upon the screen increases with decrease in condenser diameter, but at the same time the brightness of the margin decreases, thereby offsetting to a large extent the advantage of higher light output to the screen. This is equally true with both types of condenser, spherical and aspheric, although the character of the curves differs somewhat. This difference is brought out by a comparison of the curves for the 45-mm. spherical and aspheric condensers which are plotted in Fig. 11. It may be noted that with the aspheric condensers the maximum screen light output occurs when the film-gate is located closer to the theoretical plane of the light-source image than with the spherical condensers. This gate position occurs, as might be expected, at the point where the light-beam emerging from the condenser has the least divergence.

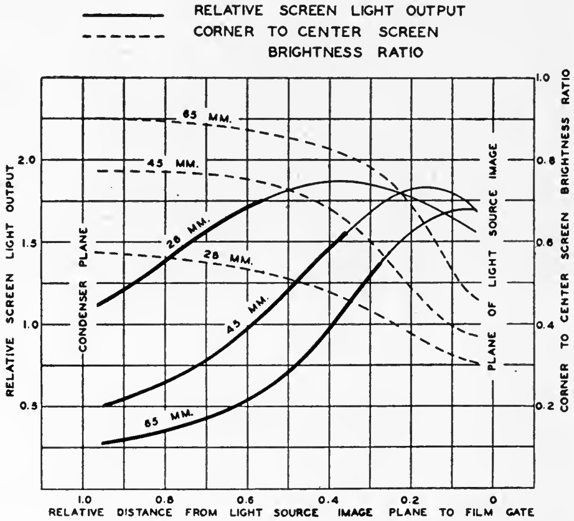

FIG. 10. Photometric data for aspheric condensers of 2.08*X* magnification (26, 45, and 65 mm. in diameter).

Fig. 12 presents the curves obtained with the 45-mm. aspheric condensers of various magnifications, *i.e.*, 1.39*X*, 2.08*X*, 3.12*X*. Two facts are noteworthy: first, that the differences between the light output curves are relatively unimportant; and, second, that the corner-to-center screen brightness ratio becomes higher with increasing magnification.

In order to supply more direct comparisons, values of the screen light output and the brightness ratio with the film-gate at the point where striations disappear are listed, for all the condensers tested, in Table II. Values of the effective light-source size required for filling the exit pupil of the system for the same film-gate position are also tabulated. On the one hand, it may be noted that for condensers of equal magnification—and this applies to both the spherical and the aspheric types—the light-source size increases with increasing focal length; on the other hand, the decrease in light-source size accompanying an increase in magnification is much smaller than would be expected on a theoretical basis. Both these effects may be ascribed to the aberrations resident in condenser lenses. The residual aberrations are, as a rule, greater the longer the focal length and the higher the magnification. Were it not for this and for the displacement of the film-gate to allow for screen uniformity, the light-source size should be the same with condensers of equal magnification, and inversely proportional with condensers of increasing magnification. In comparing spherical and aspheric condensers of equal focal length and magnification, we find that the light-source required by the latter

TABLE II

Projection Data

Condenser Data					Effective Light-Source		Screen Illumination Data	
Curvature	Diam. (Mm.)	E. F. (Mm.)	Mag. *X*	*Distance *B* — *C* (Mm.)	Dimensions (Mm.)	Shape	Relative Light Output	Brightness Ratio: Corner to Center
Spherical	26	12.9	2.08	25.3	8.8 × 9.4	Oval	1.47	0.42
	45	23.0	2.08	36.5	11.1 × 11.4	Oval	1.22	0.71
	65	33.4	2.08	45.7	13.7	Round	1.02	1.01
Aspheric	26	12.5	2.08	18.6	7.5 × 8.0	Oval	1.75	0.53
	45	22.6	2.08	22.0	9.2 × 9.5	Oval	1.55	0.66
	65	33.2	2.08	25.0	10.8 × 11.0	Oval	1.38	0.77
Aspheric	45	23.1	1.39	13.7	10.0 × 11.0	Oval	1.73	0.39
	45	22.6	2.08	22.0	9.2 × 9.5	Oval	1.55	0.66
	45	23.1	3.12	37.0	9.0	Round	1.37	0.81

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* Represents separation between film-gate and plane of light-source image necessary to eliminate screen striations. (See Fig. 4.)

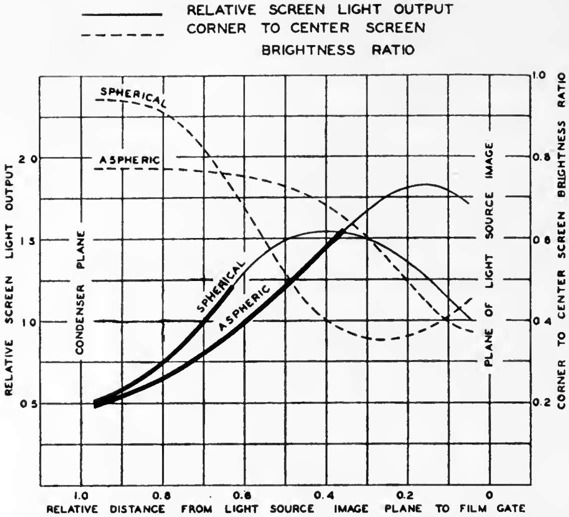

FIG. 11. Comparison of photometric performance of 45-mm. spherical and aspheric condensers of equal magnification (2.08X) and approximately equal focal length (f = 23.0 mm. for spherical, 22.6 mm. for aspheric).

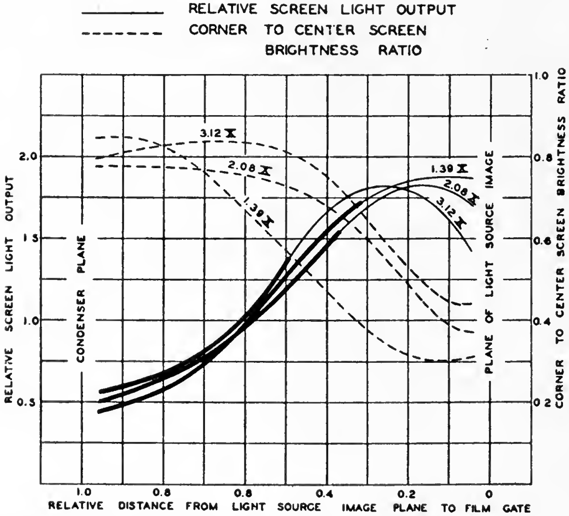

FIG. 12. Photometric data for aspheric condensers of various magnifications (45 mm. in diameter).

is smaller than that required by the former. This confirms the fact already evident from the photographs in Fig. 3, that the residual aberrations are much less with aspheric than with spherical condensers.

CONCLUSION

Assuming that a corner-to-center screen brightness ratio of 0.6 is the minimum acceptable in practice, it appears from a survey of the test results (Table II, in particular), that aspheric condensers of approximately $2X$ magnification and fairly short focal length, but larger than 26 millimeters in diameter, will afford the best compromise between efficiency and screen brightness uniformity in the design of 16-mm. optical systems.

REFERENCES

[1] MILI, J. T.: "Biplane Filament Construction—a High-Intensity Incandescent Lamp Light-Source for Motion Picture Projection," *J. Soc. Mot. Pict. Eng.*, **XIX** (July, 1932), No. 1, p. 829.

[2] KELLNER, H.: "The Function of the Condenser in the Projection Apparatus," *Trans. Soc. Mot. Pict. Eng.*, **II** (1918), No. 7, p. 51.

COLOR-BLINDNESS AND ANOMALIES OF VISION*

D. B. JUDD**

***Summary.**—Normal persons can make visual distinctions of three types: light from dark, yellow from blue, red from green; light-dark being the most primitive type of discrimination, and red-green the last acquired. Some otherwise normal persons fail to develop in their organs of sight more than a vestige of the mechanism for red-green discrimination. They are called red-green blind, or partially color-blind. A few persons have only the ability to make light-dark discrimination; they are called totally color-blind. These types of abnormality are discussed and tests for red-green blindness described.*

I. Introduction
II. The normal observer
    (1) *Structure of the visual mechanism*
    (2) *Appearance of the spectrum*
III. Types of abnormality
IV. Red-green blindness
V. Tests for color-blindness
VI. References for further reading

I. INTRODUCTION

The worker in color is frequently brought face to face with the fact that not everyone sees color as he does. Sometimes he calls two colors nearly identical which another observer will say differ importantly, and at other times the two observers will use color names for a single sample which indicate a very large appearance difference. The color worker has, therefore, to defend his own color judgments against the contrary opinion of others, and many times these differences are not mere language troubles, but are real.

Those who "sell color" in one form or another (paints, dyes, cosmetics, textiles, chromatic motion picture film) to the public will find it to their interest to be sure that they, or those whom they employ

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** Colorimetry section, National Bureau of Standards, Washington, D. C.

for their color work, have vision not much different from that of the general public. It is estimated that about five per cent of the total population have color abnormalities of fairly important degree, that is, important enough to disqualify them in many types of color work.

The purpose of this paper is to list the principal types of abnormal chromatic vision, to indicate the various terms used in their description, to discuss briefly the type of abnormality called red-green blindness (inability to distinguish red from green), which causes most trouble in color work, to describe tests for red-green blindness, and to indicate sources of further information.

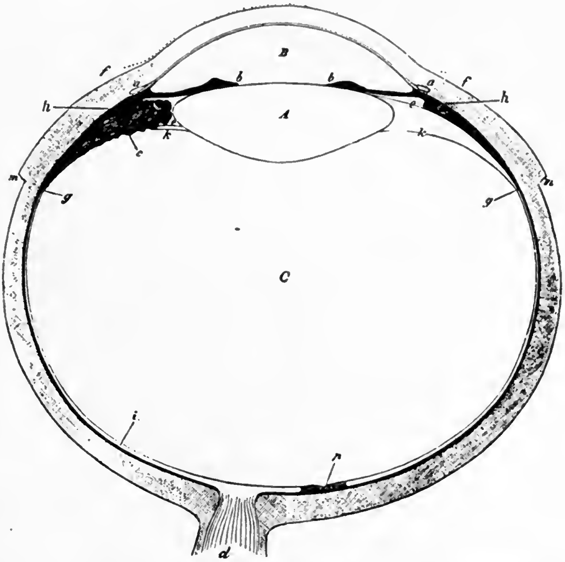

FIG. 1. Horizontal median section of the human eye (*Helmholtz*[10]).

II. THE NORMAL OBSERVER

Before describing the symptoms by means of which an abnormal observer may be detected, it is necessary to give some account of the structure and working of the normal visual mechanism.

(1) *Structure of the visual mechanism*

By visual mechanism is meant the eye and its attached nervous and muscular structures (optic nerve, brain, muscles of speech). Fig. 1 is a diagram of a horizontal section through the center of the eye.

Light enters the eye at the tear-film (*f*) covered, curved surface of the *cornea* (*a*), which serves as the principal means of focusing light from distant objects upon the retina (*g*, *i*, *n*, *g*). In its passage from the cornea to the center of the retina (*n*) light passes through the aqueous humour (*B*), the iris diaphragm (*b*, *b*), the crystalline lens (*A*), the vitreous humour (*C*), and the macular pigment near (*n*). The *iris diaphragm* (*b*, *b*) controls the amount of light entering the eye. If the illumination is high, the *pupil* of the diaphragm becomes smaller, restricting the light to the central part of the crystalline lens, which is best suited for the production of sharp images. The focusing of the eye upon near objects is accomplished by thickening of the *crystalline lens* (*A*), the change in shape being permitted by (*B*), a watery fluid called the *aqueous humour*. The *vitreous humour* (*C*), a jelly-like semi-rigid mass, fills the interior of the eye and gives it shape and solidity. The *macular pigment* is an irregular yellow spot covering the central 3 to 12 degrees of the retina, including the *fovea* (*n*), or point of clearest vision, which subtends about 1 degree.

Variation in the amount of macular pigment is a major cause of chromatic disputes among normal observers. Many colorimeters are so designed that the macular region of the retina is used exclusively, and two normal observers will, in general, make identical settings on such colorimeters only when they have equal macular pigmentation. For such colorimeters it has been proposed to supply each observer having a naturally weak macular pigmentation with an external yellow (glass or gelatin) filter to make his color-matches agree with those of the more heavily pigmented observer. Color-matching of the highest precision, however, requires that use be made of a retinal region considerably larger than the extent (4°) of the usual macula; two samples requiring within the macula an adjustment of pigmentation of the observer will for their accurate color-matching not appear equally well matched over a large area of the retina; if they happen to match for the extra-macular retina, the projection of the macular pigment may be seen on either sample when they are side by side, although either will appear perfectly uniform when viewed separately. Thus the macular pigment prevents making, for certain types of samples, a color-comparison of highest precision, and no adjustment by external filters is of assistance. Dark-eyed observers tend to have heavy macular and, indeed, heavy general pigmentation of the retina; albinos have none. Blue-eyed blondes and red-haired observers tend to have light macular and retinal pigmentation.[1]

The *retina* (g, i, n, g) contains a number of layers of nerve fibers and cells as well as the layer of receptors, or light-sensitive elements, of vision. The nerve fibers are in contact with the vitreous humour (C), and the receptors (rods and cones) are in contact with the retinal pigment (dark brown or black pigment), which is the outermost layer of the retina; so the light has to penetrate the nearly transparent layers of nerve structures before it reaches the rods and cones. Although the nerve structures cast no shadows, the blood vessels of the nerve-fiber layers are opaque and become visible whenever they are so illuminated as to cast their shadows upon unaccustomed rod-cone areas. Blood corpuscles flowing in these capillaries also cast visible shadows and may be seen as dancing specks (called *muscae volitantes* or "flying gnats") by looking at any bright uniform surface such as the blue sky. Opaque structures in the vitreous humour also cast shadows upon the retina which may be seen under these same conditions. If the structure is close to the retina the shadow is sharply defined; such shadows often appear in the form of tangled fibers or strings of beads. Many ill-defined shadows may also be seen which correspond to semi-detached debris drifting about in the liquid parts of the vitreous humour. With a motionless eye, these shadows are rarely seen, but a quick eye-movement will often bring to attention shadows otherwise too ill-defined to be seen. These slow-moving shadows follow the fixation point in a general way, lagging behind a quick eye-movement, then over-shooting when the eye is brought to a stop. They should not be confused with the "flying gnats" which dart rapidly about in every direction all over the visual field when the eye is motionless. These and kindred phenomena are called *entoptic* phenomena. Light not absorbed by the rods and cones is completely absorbed by the retinal pigment.

The *rods* are extremely sensitive to weak light; they are responsible for our vision in twilight. They do not yield chromatic vision, however; hence, twilight vision is achromatic vision; objects in twilight are either white, gray, or black, and of no other color. In strong light such as daylight the rods quickly lose their sensitiveness as if by complete bleaching of the light-sensitive substance which they contain; they have, therefore, little to do with daylight vision.

The *cones* are responsible for chromatic vision and for light-dark discriminations in daylight as well. Each retina, having roughly one square inch of area, is studded with about half a million cones. As stated by Purdy,[2] "The rods and cones have a characteristic distribution on the retina. The fovea and its immediate surroundings contain only cones; they make up the central *rod-free* area of the retina. Just outside this area, a few rods are intermingled with the cones, and the rods become more and more numerous as the edges of the retina are approached. The extreme periphery contains an overwhelmingly large percentage of rods, but is not quite free of cones." The absence of rods from the central 2 degrees including the fovea means that the normal retina has a central blind-spot (*scotoma*) in twilight, which is the basis of Arago's oft-quoted statement, "To see a very weak light, it is necessary not to look at it." Thus, to see a very faint star one must not try to look directly at it, but a little to one side of it. On account of this central blind-spot, twilight vision (rod vision) is often called *scotopia*, or *scotopic vision*. Daylight vision (cone vision) is often called *photopia*, or *photopic vision*. Daylight vision, or chromatic vision, is best at the very center of the retina, and poorest or nearly non-existent at the periphery.

The presence of two separate systems of receptors (rods and cones) in the retina immensely extends the adaptability of our visual organs. The sensitivity of the retina increases fairly rapidly by adaptation to darkness and decreases even more rapidly by exposure to strong light, the total variation in sensitivity being by a factor of more than 50,000. Variation in pupil size gives an additional factor of about 20, making in all a variation of more than a million-fold. If the retinal rods for any reason become non-functional, night blindness (normal for barnyard fowls) results. If the cones become non-functional, *photophobia* (fear of light) or even *hemeralopia* (total or partial day blindness, normal for owls) results.

The visual response from daylight stimulation of any small central area in a normal eye can vary in three different ways; that is, a mixture of at least three lights, each having a different chromaticity (such as a red, a green, and a blue light) is required to match all the colors resulting from activity of a normal eye, each light being independently adjustable in amount. A normal observer is therefore called a *trichromat.* Similarly a partially color-blind observer who can get along with only two of these components in his light mixture is called a *dichromat;* and a totally color-blind observer requiring only one, a *monochromat.*

When the light is absorbed within or near a cone, chemical processes are released which result in a nerve impulse in the fiber which is attached to it. This impulse continues to the end of the short fiber (only a few hundredths of an inch in length) where a connection (*synapse*) is made with another short nerve-fiber or *bipolar cell.* The bipolar cell in turn connects with a nerve-fiber (*axon*) of the optic nerve and a chance is provided also for sidewise communication.

The result is that, in general, outside the fovea several receptors are connected with the same bipolar cell, and many bipolar cells share the same axon of the optic nerve. But in the fovea each cone has its own bipolar cell and optic nerve axon extending to the brain; this makes for relatively acute vision in the fovea. The nerve impulse travels in this way through the retina in a direction opposite that taken by the light; and on the innermost surface of the retina, which is in contact with the vitreous humour, the impulse is conducted by the axons of the optic nerve to the exit point of the optic nerve, at which point all the axons or "wires" join to make up a "cable" called the optic nerve (*d*, Fig. 1). It is evident that there must be a hole in the retina to let the optic nerve pass through. Light falling upon this hole does not affect any normal rods or cones; it is called the *blind spot* although recent discoveries[3] indicate that it is relatively insensitive rather than completely blind. The blind spot may be demonstrated by looking at Fig. 2 with the left eye held about eight inches from the page. When the cross is fixated, an adjustment of the distance between the eye and the figure and a slight reorientation of the page will cause the

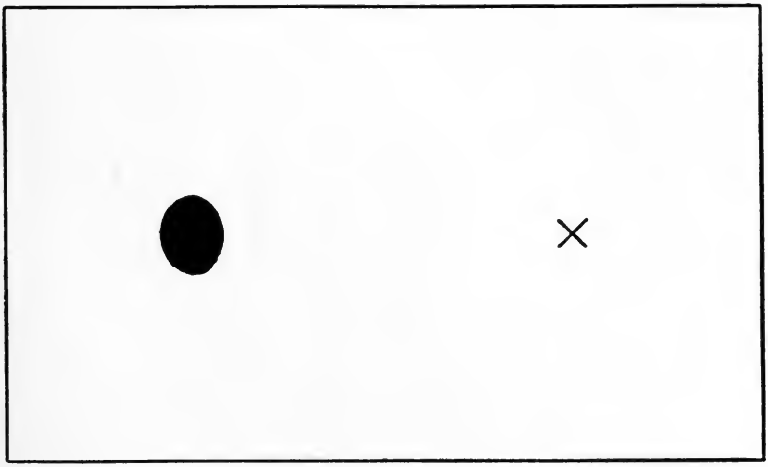

FIG. 2. Demonstration of "blind-spot": hold the page about 8 inches from the left eye and with the right eye closed, look at the cross.

image of the black spot to fall upon the exit point of the optic nerve. In this position the black spot will become invisible provided, of course, that the right eye be closed.

The course of the nerve-fibers across the inner face of the retina is curved, as indicated in Fig. 3, so as to pass around the fovea instead of over it. Since the fovea does not have any nerve structures over it, the retina is thinner here in its central point (see Fig. 1) which is on this account sometimes referred to as the *foveal pit* (*n*). The curved path of the nerve-fibers around the foveal pit may be made visible by stimulating the region to the temporal side of the fovea of the dark-adapted retina of one eye with a moderately intense light. The paths of the nerve-fibers are then seen as reddish blue arcs.[4] Whether the nerve-fibers become visible when active by giving off physical light or by stimulating electrically the underlying structures (bipolar cells, rods, and cones) is a disputed point.

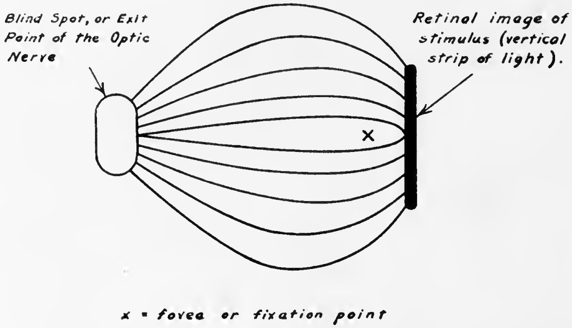

FIG. 3. The course of the long axons of the optic nerve from a region on the temporal side of the retina, around the fovea, to the exit point of the optic nerve.

In their path from eye to brain, the fibers of the optic nerves from the two eyes join at the *optic chiasmus*, at which point fibers from corresponding points of the two retinas join and run side by side through various structures of the brain to the *occipital lobe* where, in and about the median and calcarine fissures of the cortex, occurs the cortical projection of the retina. In this region there exists for every pair of corresponding points of the two eyes a single, small area served especially by fibers from those retinal points. If a region of this part of the cortex be destroyed (by a cerebral haemorrhage or gun-shot wound) a disturbance of vision affecting both eyes in the corresponding region occurs. Since these disturbances are frequently only temporary, it is supposed that the cortical projection of the retina gives the location where the coördination between the responses of the two eyes usually occurs, but that many other possible pathways exist which may be used if the accustomed pathways are destroyed.

From the calcarine and median fissures radiate millions of nerve-fibers to all parts of the brain, making possible the coördination of impulses from the eyes with those from other sense organs, and also making possible in response to retinal activity all sorts of muscular activity, the most important of which is speech.

It is to be noted that since the activity of the speech muscles reveals a triadic response to visual stimuli, there must exist not only in the retina, but at every point in the nerve-chain between retina and muscles, a possibility of at least three independent sorts of activity. Hence, it can not be said immediately of a dichromatic observer that he has a defective retinal response; the defect might exist in the nerve connections or even in a very heavy brown pigmentation of the eye media; the fact of dichromatism does not locate the seat of the defect; further evidence is necessary.

This completes the description of the structure of the normal visual mechanism. In summary, it may be noted that several "anomalies" exist in the normal observer. The fovea, point of clearest daylight vision, is blind in twilight; the macula does not respond in the same way as other parts of the retina; each retina has a rather extensive spot that is practically blind at all times; and each eye gives forms and colors (entoptic phenomena, such as the blue arcs of the retina) which correspond to structures of the eye rather than to external objects. None of these "anomalies" is troublesome in daylight vision by both eyes.

(2) *Appearance of the spectrum*

The way the normal visual mechanism works may conveniently be summarized by giving a description of the equal-energy spectrum. The equal-energy spectrum is one in which the radiant energy per unit wavelength is constant. Every visual stimulus which reaches the eye is either a portion of this spectrum or may be regarded as a combination of a number of such portions. We may therefore sketch approximately the properties of an observer by giving his description of the equal-energy spectrum.

To the normal observer the appearance of the spectrum is a series of chromatic colors varying from dim red through orange, yellow, brilliant yellow-green, green, blue, to dim violet. The brightest part of the equal-energy spectrum under usual observing conditions is at a wavelength of 555 millimicrons* (yellowish green), and from this point toward both longer and shorter wavelengths the brightness progressively diminishes. Spectrum red and spectrum blue are more saturated (stronger) colors than spectrum yellow, the least saturated spectrum color occurring at 570 mμ (greenish yellow). Fig. 4 gives for an average observer the brightness of the equal-energy spectrum as a function of wavelength relative to the brightness at 555 mμ according to several authorities.[5] Fig. 5 gives the number of doubtfully perceptible steps from an approximately achromatic color (color of sunlight or the color which a furnace would have if it could be heated to 4800°K. or 4527°C.) to the spectrum colors as a function of wavelength. The circles and dots were determined by direct observation;[6] the curve was determined by inference from determinations of the numbers of doubtfully perceptible steps between other lights.[7] The number of doubtfully perceptible chromaticity steps

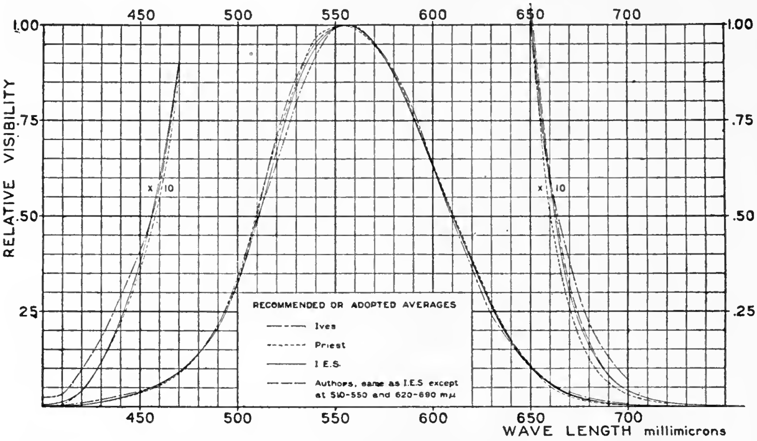

FIG. 4. Brightness of the equal-energy spectrum as a function of wavelength relative to the brightness at 555 mμ, referring to average normal daylight vision (*Gibson and Tyndall*[5]). The solid curve has been officially adopted as representative of the average observer.

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* One millimicron (mμ) = one millionth of a millimeter = approximately four one hundred millionths of an inch.

from an achromatic color is a fairly good indication of saturation; hence, Fig. 5 indicates approximately the saturation of the various parts of the spectrum.

The normal observer is sensitive to radiant energy in such a way that the spectrum has the appearance described above. It is convenient (as will presently appear) also to describe the normal observer as one who can make discriminations between light and dark, blue and yellow, and red and green.

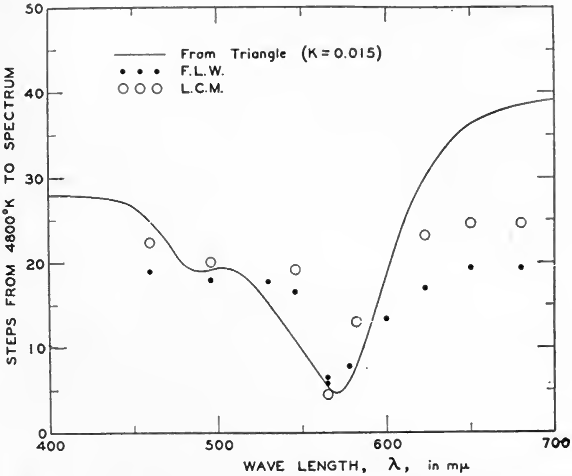

FIG. 5. Number of chromaticity steps from a Planckian radiator at 4800°K. to the spectrum as a function of dominant wavelength, referring to normal chromatic vision (*Judd*[7]).

III. TYPES OF ABNORMALITY

The chief types of abnormal vision may be discussed under the headings anomalous trichromatism, dichromatism, and monochromatism.

(*1*) *Anomalous trichromatism*

An observer possessing this type of abnormality requires a mixture of three lights to produce all the colors which he is capable of experiencing just as a normal trichromat does, but he requires proportions to produce a given color considerably different from those required by the normal observer. If he is only mildly anomalous, his description of the equal-energy spectrum will agree well with the normal; but if he is extremely anomalous, it will be a good deal like that of a dichromat. Anomalous trichromatism represents a type of vision intermediate between normal vision and red-green blindness. The distinctions made by such an observer are: light from dark, yellow from blue, and red from green; but the ability to make red-green distinctions is relatively weak.

(2) *Dichromatism*

(Partial Color-Blindness)

An observer possessing this type of abnormality requires a mixture of but two lights to produce all the colors which he is capable of experiencing. He can make two kinds of visual discrimination, one achromatic (light-dark) and one chromatic (either blue-yellow or red-green, usually the former).

(*a*) *Red-Green Blindness*

(Dichromatism with Light-Dark and Blue-Yellow Discrimination—Bee Vision)

The spectrum to an observer having red-green blindness appears in two hues only: the short-wave end of the spectrum appears blue; the long-wave end, yellow. These two bands are separated by a neutral point at about 500 mμ which has an achromatic color. From zero at the neutral point the saturation of the spectrum colors increases toward both the long-wave and the short-wave ends. There are two sub-types of red-green blindness: (*1*) abnormal brightness distribution in the spectrum, and (*2*) normal brightness distribution.

(*i*) *Red-Green Blindness with Abnormal Brightness Distribution.*—In this the spectrum is much darker in the long-wave region than it is for normal vision. This type of dichromatism is most commonly called *protanopia* by reference to the three independent processes (red, green, violet) which are usually postulated to account for normal vision. The first process (red sensation) is predominantly released by long-wave light; the second (green sensation) by light of intermediate wavelength; and the third (violet sensation) by short-wave light. Protanopia can be accounted for by considering only the second and third processes; the name, protanopia by its derivation means "first process gone." It is an improvement on the term suggested by the Young-Helmholtz theory of vision, *red-blind,* because such a term implies that protanopes see nothing but green and violet, whereas they really see yellow and blue. Adherents of the Müller theory of vision also use the designation "outer (or retinal) red-green blindness" because the Müller theory places in the retina the structural defect causing this abnormality of vision. The Hering theory does not account for it.

(*ii*) *Red-Green Blindness with Normal Brightness Distribution.*—This type of dichromatism is commonly called *deuteranopia* or "second process gone." It is the most common form of color blindness. The Young-Helmholtz theorists used to call it *green-blindness.* The Müller theorists call this abnormality of vision "inner red-green blindness" because they place in the brain the structural defect causing it. There is some doubt whether the distribution of brightness is strictly normal; some workers believe that to deuteranopes the long-wave part of the spectrum is, on the average, slightly brighter than to the normal.

(*b*) *Yellow-Blue Blindness*

(Dichromatism with Light-Dark and Red-Green Discrimination)

This is a rare form of abnormal vision associated chiefly with diseases of the eye. Objects appear to such an observer a good deal as they do by candle-light to a normal observer. Two-color motion pictures also give mostly red-green differences, and so duplicate fairly well in appearance the world of the yellow-blue blind. The spectrum to an observer having yellow-blue blindness appears in but two hues, red and green; its brightness distribution is normal. There are two types of yellow-blue blindness: (*1*) that with one neutral point, and (*2*) that with two.

(*i*) *Yellow-Blue Blindness with One Neutral Point.*—The neutral point is located at about 570 mμ, the part of the spectrum which is most nearly neutral to the normal observer. This type of dichromatism is commonly called *tritanopia* or "third process gone." The Young-Helmholtz theorists used to call it *violet-lindness.* The Müller theorists call it "outer yellow-blue blindness" as well as tritanopia, in analogy to protanopia or outer red-green blindness. To the tritanope the spectrum is red from the long-wave end to the neutral point and is elsewhere green. The Hering theory does not account for this form of yellow-blue blindness.

(*ii*) *Yellow-Blue Blindness with Two Neutral Points.*—One neutral point (or band) is located at about 588 mμ, the spectrum appearing red from the long-wave end down to this band, then green down to the second neutral point or band at about 465 mμ, the remainder appearing red. This type is so rare that many treatments of color-blindness do not refer to it. Only three or four cases have been studied and reported. It has been called "tetartanopia or inner yellow-blue blindness" by Müller who makes it analogous to deuteranopia or "inner red-green blindness." The Young-Helmholtz theory does not account for it.

(3) *Monochromatism*

(Total Color-Blindness)

An observer possessing this type of abnormality requires but a single light to produce all the colors which he is capable of experiencing; he can match any stimulus with any other stimulus merely by adjusting them to equal brightness; he is capable of light-dark discrimination, and no other kind. His spectrum does not have merely one or two neutral points; it is all neutral. There are two types: (*1*) with central scotoma, and (*2*) without.

(*a*) *Monochromatism with Central Scotoma*

(Owl Vision)

This type of monochromatism is ascribed to non-functioning of the cones. Not only do monochromats of this type have at all times the central scotoma characteristic of normal twilight vision, but they also have photophobia, or fear of light, which is characteristic of owls and of the normal dark-adapted observer, and which is ascribed to rod vision. Further common characteristics of such observers are low visual acuity and *nystagmus* or side-to-side eye-movements as if in an attempt to improve deficient visual acuity by using retinal areas now to the one side, now to the other side of the central blind area.

(*b*) *Monochromatism without Central Scotoma*

(Cat Vision)

This type of monochromatism is characterized by normal visual acuity as well as good foveal vision; it can not be ascribed to the failure of the cones to function, but is ascribed to failure of the chromatic functions either retinal or cortical.

IV. RED-GREEN BLINDNESS

This type of dichromatism deserves special attention because in the first place it is by far the most common, being inherited by about 3 per cent of men and one-tenth of one per cent of women. Thus, a girl has little chance of inheriting incompletely developed eyes, but she has a good chance of inheriting an incomplete ability to transmit normal vision to her sons. The sons of a normal man and a woman of normal vision may thus be dichromats, but it is believed that the daughters will inherit dichromatism only provided that both father and mother be abnormal in those respects.

Another curious thing about congenital red-green blindness is that although it is a sufficiently serious abnormality to disqualify its possessor for color work, it is possessed by otherwise normal, healthy persons who may live their lives through without discovering that their chromatic vision is at all abnormal. Usually, of course, a dichromat gets into all manner of arguments about the appearance of things and begins to suspect something; and, of course, when he learns to drive an automobile on city streets and has to discriminate the red from the green traffic lights, he may conceal his defect from others but can no longer conceal it from himself. Traffic signal red is a yellowish red, seen as yellow by the red-green blind; many of the green traffic signals have purposely been made bluish green so that red-green blind observers would see the signal as weak blue and so be able to tell it from the red signal.

There are in addition to true red-green blind observers, or dichromats, perhaps about an equal number of anomalous trichromats of such extreme degree of anomaly that they are no more eligible for color work than dichromats themselves; that is, they possess the ability to make red-green distinctions only in a slight degree, so that they must have either very strong reddish and greenish lights, or a very pronounced red-green difference, or a very large part of the retina stimulated, or a very long time for decision in order to be sure of a red-green difference. Such extremely protanomalous or deuteranomalous observers have visual systems much more like a protanope or deuteranope than like a normal observer; they can, for example, discriminate the red from the green traffic light when they are close to the semaphore and have a number of seconds in which to make the decision, but are nearly as much at a loss as true dichromats to do it in fast-moving traffic. Or, they might distinguish a red apple from a green one by its color nearly as quickly as a normal observer, but would be unable to tell brass from copper with any assurance. What is to be said about red-green blind observers, therefore, applies nearly as well to these extremely anomalous trichromats.

Fig. 6 shows the relative brightness (luminosity) of the equal-energy spectrum for a protanope, a deuteranope, and a normal observer, according to Pitt.[8] Note that the three curves are very similar except that the curve for the protanope is much lower for wavelengths greater than 560 mμ; that is, the protanope is relatively insensitive to long-wave light.

Fig. 7 shows, as a function of wavelength, the number of chromaticity steps from the neutral point for protanopes and deuteranopes, derived from Pitt's results. This number is a fairly good estimate of the saturation of the spectrum for red-green blind observers. At the neutral point, the saturation of the spectrum color is zero; to the left of the neutral point the hue is blue, and the saturation rises steadily up to about 430 mμ; to the right of the neutral point the hue is yellow, and the saturation rises rapidly to a smaller maximal value near 540 mμ, above which no further distinct chromaticity change occurs. According to these results the deuteranope has chromatic vision superior to that of the protanope, being able to make about 50 per cent more distinctions. For comparison a part of the curve in Fig. 5 indicating saturation of the spectrum colors for the normal observer is also shown. This comparison indicates that the saturation of the spectrum colors for the normal observer is everywhere superior to that of the red-green blind except possibly between 550 and 590 mμ, where the deuteranope, in particular, seems to have an advantage. We should expect, however, that the normal observer

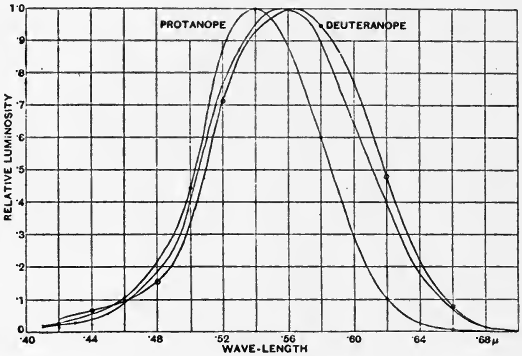

FIG. 6. Relative brightness of the equal-energy spectrum for a protanope, a deuteranope, and a normal observer (*Pitt*[8]).

would not be inferior in this respect for any region of the spectrum, and since the size of doubtfully perceptible chromaticity steps depends importantly upon the exact experimental conditions used, the indicated superiority of the red-green blind observers is probably not significant.

These curves (Figs. 6 and 7) indicate what it is believed the red-green blind observers see when they look at the spectrum, but it should be emphasized that they do not indicate the color names which will be used by such observers in describing what they see. The naming of colors by a dichromat gives virtually no clue to what he is seeing. According to Pitt,* "An interesting demonstration of the fact that color-naming is a bad test was unconsciously given by a protanope. He was shown a colored plate in a book, containing three distinct colors—red, green, and yellow. He was asked what color the red was. His first answer was green, but within a second he had changed his mind and called it red. After his first answer he had allowed his eyes to wander on to the other colors, and, although they looked the same color to him he could discriminate between them by means of their intensity (brightness) difference. The brightest he called yellow, the next brightest green, and the faintest red."

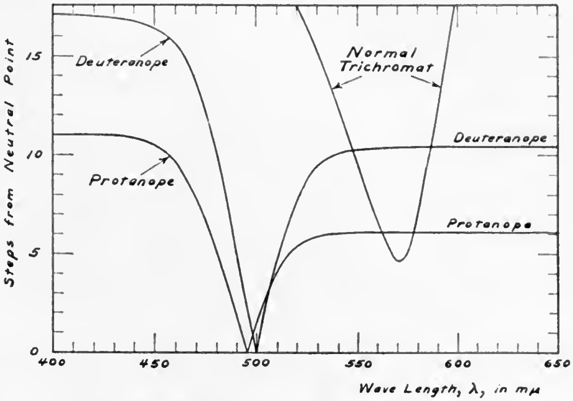

FIG. 7. Number of chromaticity steps from a nearly achromatic color (Planckian radiator at 4800°K) to the various spectrum colors for protanopes, deuteranopes, and normal trichromats.

Table I, from Pitt,* shows the descriptions of the spectrum colors

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* *Loc. cit.*, p. 33.

given by five dichromats—three deuteranopes and two protanopes. It is evident from the remarks of the dichromats that their color names do not correspond with those used by normal observers, and the question may be raised, "How do we know what the dichromat really sees? Why do we call it red-green blindness?" Strictly speaking, we do not know with certainty what the dichromat sees, any more than we can be sure what a normal observer sees. Philosophers will tell us that each observer is separate unto himself, and no observer will be certain that any other observer experiences the same sensation called (for example) yellow as he does. Practically speaking, however, no one entertains any serious doubts that all normal observers experience about the same sensations; there is no reason to believe the contrary. And with nearly the same degree of certainty it is believed that the protanope and the deuteranope see light and dark, blue and

TABLE I

Descriptions of Colors by Five Dichromats—Three Deuteranopes and Two Protanopes

Description by Normal Observer	Wave-length, mμ	Remarks by the Dichromats				
		D_1	D_2	D_3	P_1	P_2
Red	658–780	Yellow	Orange	Yellow-green	Dark color —red?	Orange
Orange	600–658	Yellow (warm)	Yellow	Orange-green	Yellow	Lemon
Golden yellow	583–600	Yellow	Yellow	Orange-green	Yellow	Lemon
Yellow	578–583	Yellow	Yellow (orangy)	Orange-green	Yellow	Yellow
Greenish yellow	567–578	Yellow	Yellow (orangy)		Yellow	Yellow
Green	524–567	Greenish yellow	Yellow-white	Yellow	Yellow nearly gone, may be red?	Light yellow to white
Blue-green	502–524	Whitish	Pink	Yellow	Yellow gone, nearly green	Blue
Blue	431–502	Blue	Mauve	Blue	Green	Royal blue
Violet	390–431	Blue	Blue	Blue	Dark color	Violet

yellow, the gap between trichromat and dichromat having been bridged by the reports of a few observers who have normal vision by one eye and dichromatic vision by the other.

In Table II there are listed a number of "confusion colors" for protanopes, that is, the color-names by means of which normal observers identify colored samples which can be distinguished by dichromats, if at all, only by their lightness difference. Table III is a similar table for deuteranopes. The information in both tables is taken from Pitt.

TABLE II

Normal Color-Names for Colors of Nearly Identical Chromaticity for Protanopic Observers

Wavelength, mμ	
496	Light blue, gray
499	Green, ivory, fawn, light stone, pink
502	Nile green, cream, brown, purple-brown
505	Mid-Brunswick green, middle stone, deep cream, crimson
509	Sea-green, bronze green, deep stone, primrose, buff
515	Light Brunswick green, red
525	Yellow, orange

TABLE III

Normal Color-Names for Colors of Nearly Identical Chromaticity for Deuteranopic Observers

Wavelength, mμ	
500	Light blue, gray
504	Green, ivory, light stone, fawn, pink
506	Nile green, brown
508	Mid-Brunswick green, cream, middle stone, purple-brown
511	Sea-green, deep cream
514	Light Brunswick green, bronze green, primrose, deep stone
517	Buff, crimson
530	Yellow, red

Each table gives also the wavelength of the equivalent spectrum stimulus, and serves to emphasize a fact often overlooked, that every color experienced by a dichromat is a duplicate of one of his spectrum colors provided the brightness be correctly adjusted. The normal observer requires a mixture of two parts of the spectrum to duplicate the chromaticity of all the colors which he experiences. The color-names given by Pitt are those extensively used in the British paint trade; whenever American usage differs importantly from British, the American equivalent has instead been given in Tables II and III, taking the Maerz and Paul *Dictionary of Color* as the authority.

Tables II and III give a good idea of the wide diversity of color names to be expected from a dichromat in describing the spectrum colors. For example, according to Pitt we would expect a protanope to be able to match a green, an ivory, a fawn, a light stone, and a pink color all with the spectrum color at 499 mμ; so he would be right in describing this spectrum color by any of these color names. Table III is probably more useful for estimating what colors a deuteranope will confuse than Table II is for the protanope, because two samples of the same lightness to a normal observer will appear of nearly the same lightness for the deuteranope. The normal observer can therefore tell whether two colors will be distinguished by the deuteranope because of lightness alone; but he can not make a very reliable estimate for the protanope. As shown in Fig. 6 the protanope responds but slightly to long-wave light which is copiously reflected by red samples; he therefore sees red or reddish samples considerably darker than the normal observer does, and his actual groups of confusion-colors differ more from those of the deuteranope than is indicated by comparison of Tables II and III, which consider chromaticity confusion but not light-dark confusion.

With some limitation Tables II and III serve to indicate also the confusion-colors of anomalous trichromats of extreme type. Thus, an extremely deuteranomalous trichromat will tend to confuse the same colors as a deuteranope, but since his red-green discriminatory power is weak instead of non-existent, he will see pronounced red-green differences invisible to a deuteranope. He might, for example, confuse light green with ivory, or pink with ivory, but still be able to distinguish pink from light green if permitted to make a critical examination of the samples.

A characteristic of most observers having abnormal chromatic vision, be it dichromatism or anomalous trichromatism, is hesitation in making a color judgment; they are accustomed to let the other fellow name the color and then to agree with him.

V. TESTS FOR COLOR BLINDNESS

These tests are designed chiefly to detect protanopes, deuteranopes, and extremely anomalous trichromats, because not only are such observers more numerous and more difficult to discover than other types of abnormal observers, but also these types of vision are particularly unsuited to speedy discrimination of traffic, railway, marine, and aviation signal lights. The successful tests all have the following properties in common: (*1*) they present reds and greens which the subject of the test must distinguish; (*2*) they present them in small areas so that anomalous trichromats as well as dichromats will be discovered; (*3*) they present them intermingled with other colors in such a way as to discourage attempts upon the part of the subject to conceal either defective vision by guessing, or normal vision by making mistakes on purpose; and (*4*) they present reds, greens, confusion and background colors of a variety of lightnesses so that the subject can not get any clue about the colors from his ability to discriminate light from dark. The various successful tests differ essentially only as to the form of response required of the subject. The following tests have been successfully used at the National Bureau of Standards:

(*1*) *The Holmgren Wool Test.*—A number of small varicolored skeins of wool are spread out before the subject, who is required to select those resembling three larger skeins, a red, a green, and a rose.

(*2*) *The Nagel Charts.*—A number of cards are shown to the subject, each card having a series of small circular colored spots arranged in a circular ring. The spots on some of the cards are all weak green, some light and some dark; others are combinations of green with gray, pink, and other confusion-colors, and so on. The subject is required to say which cards bear spots of but one hue and which have more than one hue.

(*3*) *The Stilling Charts.*—The irregular and varicolored spots on these charts are so arranged and colored that a digit can be read by a normal observer on each chart. Some of the charts can not be read by dichromats and extremely anomalous trichromats; and some are hard even for a normal observer to read.

(*4*) *The Ishihara Charts.*—This improved form of Stilling chart supplies both cards which can be read by the normal observer but not by dichromats, and cards which can be read by dichromats but not by normal observers. In addition, there are cards which yield one digit when read by a normal observer and a different digit when read by a dichromat; and there are charts for testing the vision of observers who can not read numbers on which, instead of a digit to be read, there is a continuous path to be traced.

VI. REFERENCES FOR FURTHER READING

The elementary treatment of vision by Purdy[2] gives a readable and more complete account of normal vision than has been included here. *An Introduction to the Study of Colour Vision*, by Parsons,[9] gives a brief summary of nearly all important work up to 1920. In addition to a good chapter on the chief facts of dichromatism, there is a section devoted to the chief theories of vision which have been mentioned here only because of their influence on terminology. Helmholtz's *Treatise on Physiological Optics*[10] is the most authoritative and complete reference work on vision. An important summary and classification of all types of abnormal vision is given in German by G. E. Müller.[11] Unfortunately there is no English translation. Müller's classification has been followed closely in the present discussion of the chief types of abnormal vision. The most thorough quantitative investigation of red-green blindness with modern apparatus is that of Pitt[8] from whose results Fig. 6 and Tables I, II, and III have been taken.

REFERENCES

[1] HELSON, H., AND GUILFORD, J. P.: "The Relation of Visual Sensitivity to the Amount of Retinal Pigmentation," *J. Gen. Psych.*, **9** (July, 1933), No. 1, p. 58.

[2] PURDY, D. McL.: "Psychology—a Factual Textbook" (edited by Boring, Langfeld, and Weld), *John Wiley & Sons* (New York), 1934.

[3] HELSON, H.: "The Effects of Direct Stimulation of the Blind-Spot," *Amer. J. Psych.*, **41** (July, 1929), No. 3, p. 345.

[4] JUDD, D. B.: "Least Retinal Illumination by Spectral Light Required to Evoke the 'Blue Arcs of the Retina,' " *Bureau of Standards, J. of Research*, **2** (Feb., 1929), No. 2, p. 441.

[5] GIBSON, K. S., AND TYNDALL, E. P. T.: "Visibility of Radiant Energy," *Scientific Paper No. 475*, **19** (Aug. 11, 1923), p. 131. The curve recommended by these authors was subsequently adopted by the International Commission on Illumination as representative of the average observer.

[6] MARTIN, L. C., WARBURTON, F. L., AND MORGAN, W. J.: "Determination of the Sensitiveness of the Eye to Differences in the Saturation of Colors," *Medical Research Council*, Reports of the Committee on the Physiology of Vision, **XIII**; Special Report Series No. 188 (London), 1933.

[7] JUDD, D. B.: "A Maxwell Triangle Yielding Uniform Chromaticity Scales," *J. of Research, National Bureau of Standards*, **14** (Jan., 1935), No. 1, p. 41; RP756.

[8] PITT, F. H. G.: "Characteristics of Dichromatic Vision," *Medical Research Council*, Report of the Committee on the Physiology of Vision, **XIV**; Special Report Series, No. 200 (London), 1935.

[9] PARSONS, J. H: "An Introduction to the Study of Colour Vision," (2nd ed.), *Cambridge University Press*, 1924.

[10] HELMHOLTZ, H. v.: "Treatise on Physiological Optics," English Ed. (edited by J. P. C. Southall, *Optical Soc. Amer.*), 1924.

[11] MÜLLER, G. E.: "Darstellung und Erklärung der verschiedenen Typen der Farbenblindheit nebst Erörterung der Funktion des Stäbchenapparates sowei des Farbensinns der Bienen und der Fische (Representation and Explanation of the Different Types of Color Blindness, Including Discussion of the Function of the Rods as in the Color Vision of Bees and Fishes)," *Vandenhoeck & Ruprecht* (Göttingen, Germany), 1924.

AIR FILTRATION IN THE PRODUCTION OF MOTION PICTURES*

H. C. MURPHY**

Summary.—*A consideration of present practices in the art of cleaning air, beginning with a description of the solid impurities found in the air in industrial centers and in a number of large cities of the United States. The historical development of air cleaning is described briefly, with particular attention to adhesive impingement filters, automatic viscous filters, dry air-filters, and electric precipitators.*

It is difficult for the human mind to conceive the infinite forms and varieties of dust. Every material in the universe enters into its composition, every form and shape is represented in the countless particles stretching from the earth's surface to the outer reaches of space. However, the dust which ordinarily constitutes our commercial and industrial dust problem is capable of being investigated readily. Dust usually consists of soot and unconsumed carbons, fibers, decayed animal and vegetable matter, pollens, tree dusts, bacteria, molds, *etc.*, varying in diameter from the objectionable cinder which is sometimes caught in the eye to particles of almost inconceivable smallness. The pollen of giant ragweed, for instance, is approximately 20 microns, or 0.0008 inch, in diameter. Some idea of their relative size may be gained from the fact that 40 of these granules placed side by side would reach barely across the center of an ordinary pin-hole, and more than 1400 could pass through the same pin hole at one time without crowding.

The diameter of the average human hair (Fig. 1) is approximately 100 microns (0.004 inch). The bacillus of pulmonary tuberculosis has a length of from 2 to 6 microns (0.00008–0.00024 inch) and a width of 0.5 micron. The ordinary blood corpuscle is approximately 14 microns (0.00056 inch). Investigators recently found the cellulose molecule to be 1.5 microns (0.00006 inch) in longest diameter.

The Scotch investigator, Aitken, proved that some dust particles

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** American Air Filter Co., Louisville, Ky.

are so fine that they remain suspended in the air for two years or longer, passing several times around the earth and probably ascending to heights of 40 to 50 miles. Recent airplane studies at the Massachusetts Institute of Technology showed air-borne bacteria and similar organisms at altitudes of two to three miles. In the extensive aerial explorations conducted by Col. and Mrs. Charles Lindbergh in 1933, they found many air-borne organisms over the waters and polar ice cap near the Arctic Circle.

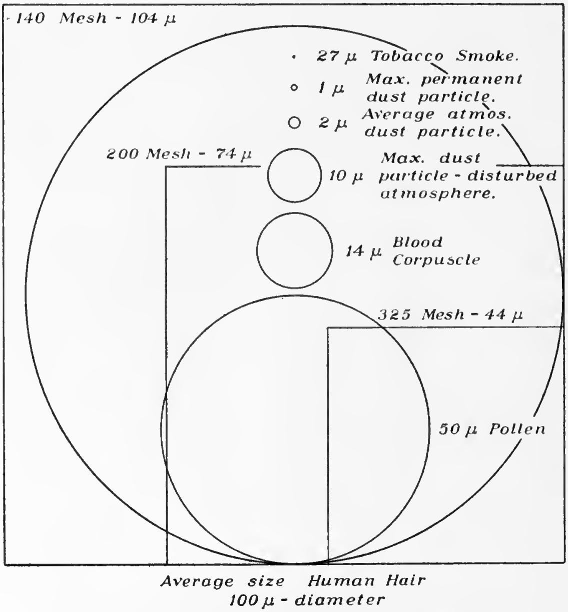

FIG. 1. Relative sizes of atmospheric impurities.

After volcanic eruptions the atmosphere often remains charged with dust particles for extended periods, giving rise to extraordinary sunsets and other remarkable chromatic phenomena. Cinders from the Chicago Fire reached the Azores 40 days after the outbreak, and science now explains the "sulphur rain," the "yellow day," and other awe-inspiring phenomena of earlier days, as well as the rapid spread of epidemics, as being results of the dispersion of dust particles in the upper currents of the air. In the war-time influenza epidemic, whole colonies in isolated islands and unfrequented localities having no communication whatever with the outside world were wiped out.

SOLID AIR IMPURITIES

The American Society of Heating and Ventilating Engineers classifies solid air impurities as follows:

Dusts are particles that are large enough and heavy enough to fall in still air with increasing rapidity, due to gravity.

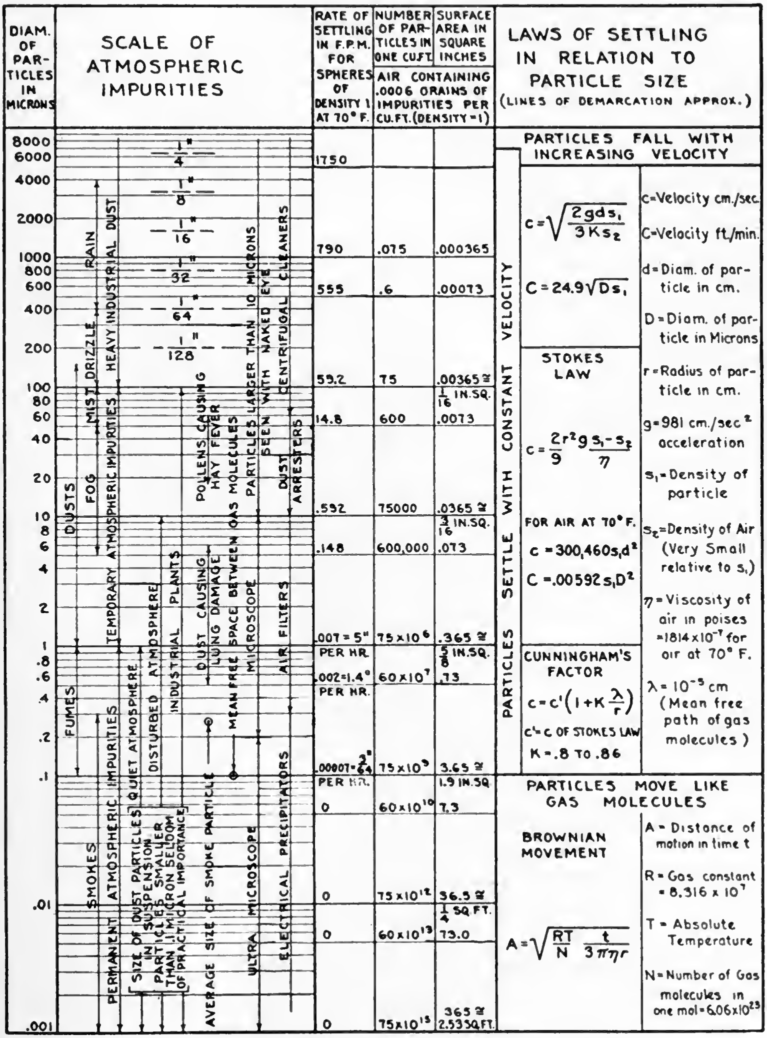

FIG. 2. Size and characteristics of air-borne solids.

Fumes are smaller particles which fall in still air, with constant rather than with increasing rapidity, due to gravity.

Smokes are particles which do not settle at all in still air, which diffuse constantly, and are actuated by the Brownian motion rather than by gravity.

There is, of course, no sharp distinction between these different classes: they merge one into the other. A very convenient scale of particle sizes of atmospheric impurities has been compiled by W. G. Frank, and is given in Fig. 2.

From this chart we note that particles whose sizes are less than 1 micron are usually permanent constituents of the air. For sizes ranging from 1 to 100 microns they are classed as temporary atmospheric impurities. For sizes greater than 100 microns they are classed as heavy industrial dusts. Particles larger than 10 microns can usually be seen by the naked eye.

Examination of a typical sample of dust from an industrial center showed it to consist of materials in the proportions shown in Table I. A dust sample from the vicinity of a paper mill had the composition shown in Table II.

TABLE I

Dust from an Industrial Center

Material	Per Cent
Smoke carbons (soot)	45–47
Siliceous matter	40–43
Coal-dust	2.5–3.5
Fibrous matter	3–4.5
Miscellaneous	6–8

TABLE II

Dust from Vicinity of Paper Mill

Material	Per Cent
Smoke carbons (soot)	40–44
Siliceous matter	20–23
Fibrous matter	25–27
Other materials	8–10
Miscellaneous	5–7

Our knowledge of the constituents and impurities in the air is very meager. While our food and water are carefully tested and checked against impurities, we do not have even a semblance of general supervision over the pollution of the air we breathe. Certain progressive communities have, it is true, conducted surveys to determine the soot fall. These gave values varying from 1950 tons per square mile per annum in Pittsburgh to 370 tons in New York. The writer personally conducted an investigation of air pollution in 24 cities over the period 1924 to 1927. The results of these investigations were as shown in Table III.

TABLE III

Fifteen Cleanest of Twenty-Four Cities Investigated in 1924–1927

City	Average Number of Dust Particles per Cu.-Ft. of Air	City	Average Number of Dust Particles per Cu.-Ft. of Air
Boston	5360	Kansas City	9,700
San Francisco	6580	New York	9,760
New Orleans	6600	Philadelphia	9,880
Denver	6740	Columbus	10,160
Washington	7800	Toledo	10,700
Des Moines	8370	Milwaukee	11,460
Minneapolis	8470	Baltimore	11,980
Atlanta	9460		

Later in 1929, these cities were again investigated, and while there was definite improvement in a number of the smokier cities, there was some doubt as to whether this was due to lessened industrial activity or to the improved utilization of fuels.

Investigations in this country and abroad have shown a surprisingly close relation between excessive pollution of city air and abnormal prevalence of respiratory infections. Investigations conducted in Pittsburgh by the Mellon Institute established the relation very definitely, and many other similar investigations emphasized the relation between dust and disease. Medical science has within the last few years made remarkable progress in the treatment of certain diseases such as hay-fever, bronchial asthma and some of the other so-called allergic diseases, by air filtration. Sufferers in many of our large cities have found relief in some of the theaters, department stores, and public buildings which are supplied with modern air-cleaning systems. These "man-made hay-fever resorts" remove the pollens from the air with the air filters that were installed primarily to remove dirt, dust, and bacteria. There is a growing appreciation that the modern motion picture theater equipped with air filters not only brings relief to sufferers from hay-fever and bronchial asthma, but that it affords at least temporary relief in certain other respiratory disorders.

Physicians have for ages emphasized the importance of clean air, but the general public has been very little aware of its influence upon health. Aristotle 2000 years ago emphasized the importance of clean air, and Hypocrates, the greatest physician of antiquity, shrewdly suspected that dust was a carrier of disease germs. During the great pestilence which ravaged Athens in 429 B.C. enormous wood fires were made for the purpose of disinfecting the air.

Today engineers recognize that industrial dusts are not only a health menace but one of the most difficult problems in works management. The development of improved air-cleaning devices has been of value in many industrial processes. For example, most of the gelatin used in photographic work is manufactured in filtered air to eliminate bacterial contamination. Gelatin and glue are graded and priced according to the number of bacteria in each sample—the higher the bacteria count the lower the price per pound. There are, of course, other factors, but the bacteria count is a most important item. The author's first personal experience in bacteria removal on a commercial scale was in 1922 when he supervised the installation of viscous air-filters in a large gelatin plant with the guarantee that gelatin would be produced equivalent in quality to the imported product. After the filter installation was made, gelatin was produced with the bacteria count enormously reduced; it was, therefore, suitable for many purposes for which the contaminated product could not be used successfully. Air-filters have been installed for drying photographic plates and films in various sections of the country.

While the removal of air-borne organisms by air filtration is today well accepted and understood, our first installations for this purpose were largely a matter of deduction. Assuming that the dust particles were the carriers of the air-borne organisms, it was believed that removing 97 per cent of the dust would eliminate a larger percentage of the bacteria, as obviously every dust particle would not be a carrier of such organisms. The technic developed for drying gelatin has made it possible to make and fulfill definite guarantees as to the reduction of the bacteria count in an air stream.

PROGRESS IN AIR-CLEANING

The successive steps in the art of cleaning air have been entirely logical. First came mechanical screening, or removal by cloth or metal screens. This served, and in fact still serves for certain purposes but it was found to be far from an adequate solution of the problem—it stopped the large particles of dirt, but the smaller particles went through. For instance, ordinary commercial cement is guaranteed by the manufacturer to have passed through 100-mesh screen (145 microns—0.0058 inch). It is apparent that the 40-mesh screen ordinarily used in general ventilation work would allow a large part of the dirt to pass through. On the other hand, by its very nature, a screen fine enough to remove small dirt particles soon clogged up and obstructed the air flow. Also "coke washers" were tried, but they were open to certain inherent objections and were never commercially accepted.

A decided advancement in the art of cleaning air which practically eliminated cheese-cloth and screens from general ventilation work was the development of the air washer, or "fog filter" (so-called), which was usually a combination of a spray chamber and wet scrubbing surfaces flushed constantly with water. Various types were developed, and much ingenuity in design was shown, especially as regards the spray nozzles. Investigation showed, however, that most of the cleaning was done by the eliminator plates. About this time the characteristics of the dust problem began to change. With the advent of the automobile and our greatly enlarged manufacturing activities, street dust which had been largely wettable by water was replaced by soot and unconsumed carbons—light greasy substances insoluble in and almost totally unaffected by water.

This brought the air-cleaning problem up for solution once more; the air washer was found to be inefficient in removing soot and carbons, the great problem in modern ventilation. A. E. Stacey, research engineer of the Carrier Engineering Corporation, in a paper read before the semi-annual meeting of the American Society of Heating and Ventilating Engineers, at Cleveland in June, 1921, stated:

> In the processing of certain materials, it is essential that dust particles of every description be removed from the air. It is a well-known fact that spray type air washers will eliminate only about 50 per cent of the carbon particles from the air, which necessitates the employment of some other method of dust removal.

Moreover, it was found that air-washers under certain conditions were breeding-places for bacteria and actually contaminated the air instead of purifying it. Professor G. L. Larson, of the University of Wisconsin, presented a paper at the annual meeting of the American Society of Heating and Ventilating Engineers in New York in January, 1916. He stated as follows:

These (*bacteria*) tests showed some startling and unexpected results. When using recirculated water the washers supplied bacteria to the air instead of removing them, and even when using new water continuously did not show any marked efficiency as a bacteria remover * * * The sand filters showed conclusively that the washer delivered bacteria to the air. The four sand filter tests checked each other very closely and showed an increase of bacteria in a ratio of about two to one.

ADHESIVE IMPINGEMENT FILTERS

Attention was again directed to air-filters—so called. In reality the modern viscous air-filter does not *filter* the air at all. Cheese-cloth or screens are true filters, whereas most of the modern air-filters operate on the principle of *adhesive impingement.*

The first air-filter operating on the adhesive impingement principle was the human nostril. The short stubby hairs kept constantly moist by mucus form an air-filter that is surprisingly efficient. In fact, one manufacturer patterned his filter on this principle, replacing the hair and mucus with steel-wool and oil. Investigations showed that the dirt and dust in modern air, even soot, carbons, *etc.*, was efficiently trapped and retained on oil-coated surfaces. It was not a new idea. Before this, oiled roads and floors served to keep the dust from flying about. The originality proceeded from the ingenious arrangements of the various media, which are formed into filter units and made available for air-cleaning work. The filter media are usually coated with oil, glycerine, or like substances.

While the choice and arrangement of filtering media are almost unlimited, there are certain rather definite requirements for a practical commercial filter, which have limited the possible constructions considerably. To fulfill the essential requirements an air-filter should possess the following qualifications:

(*a*) Efficiency in dirt removal
(*b*) Low resistance to air flow
(*c*) Large dust-holding capacity
(*d*) Ease of operation

In order to attain maximum efficiency it is necessary to divide the air into innumerable fine streams: the more intimately and frequently the air is brought into contact with the viscous coated medium the better the cleaning will be. Theoretically, seven impingements are sufficient; more will give better service.

As the dirt and dust are taken from the air and collected on the adhesive coated surfaces, additional supplies of the binding liquid are continuously required in order to bind additional layers of dirt. This requirement is met in most unit viscous filters by the retention throughout the filter medium of oil droplets (Fig. 3). These droplets are held at the innumerable crossings where the wires or strands comprising the filter body touch each other. However obtained, these additional reservoirs of the binding liquid perform a most important function, allowing the oil to spread by capillary action as fresh dirt is deposited upon the filter, and binding subsequent layers until the oil supply is exhausted. The filter is washed and recharged with the proper charging liquid about once in six to eight weeks, depending upon the dust concentration.

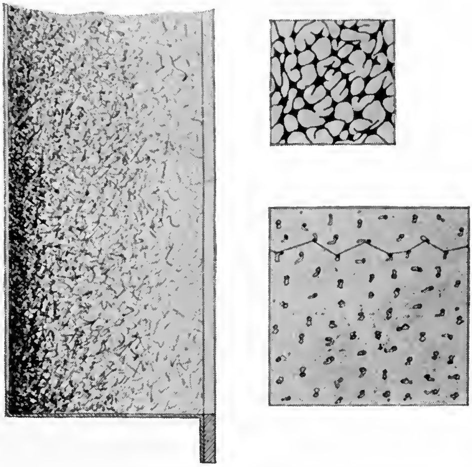

FIG. 3. Diagrammatic construction of unit air-filters.

In selecting charging liquids for viscous filters, particular attention should be paid to the characteristics of the filter and the recommendation of the manufacturer. It is obvious that a charging liquid that would be entirely satisfactory for one type of filter or one location, would be altogether unsuited for a different design or different operating conditions.

In general, charging liquids should have a viscosity at 100°F. and at zero degrees that will produce a suitable binding medium for the dust. Its surface tension at operating temperatures should not be so high as to prevent the penetration of the dust particles.

Evaporation should not exceed $^3/_4$ of 1 per cent. This is equivalent to an oil-in-air concentration of approximately 0.000007 grain per cubic foot, or less than the normal oil content of the air in many of our larger cities. The liquid should be fireproof, odorless, and should be germicidal in its action, to prevent the development of mold spores and bacteria on the filter media.

Next in importance to efficiency is the resistance to air flow—also, in the unit filter, the dust-holding capacity. Low resistance is desirable, not only from the standpoint of power economies but from the fact that air-filters are often used in existing ventilation systems where no protection against dirt is supplied. In such instances it is often inconvenient or impracticable to alter the fan arrangements so as to work against any considerable increase in resistance.

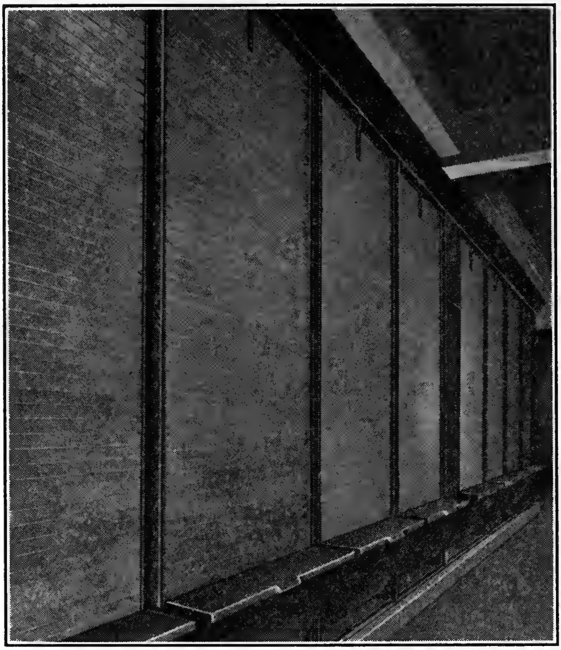

FIG. 4. Automatic viscous filters installed in eastern film manufacturing plant.

CLASSIFICATION OF FILTERS

The air-filter Code adopted by the American Society of Heating and Ventilating Engineers classifies air cleaners as follows:

Class A. Automatic.—In general all air-cleaning devices which use power automatically to recondition the filter medium and maintain a non-varying resistance to air flow.

Class B. Low Resistance, Non-Automatic.—Air cleaning devices for warm-air furnaces, unit ventilating machines, and similar apparatus and installations in which a maximum pressure of not more than 0.18 inch of water is available to move air through the air-cleaning device.

Class C. Medium Resistance, Non-Automatic.—Air-cleaning devices for systems in which a maximum pressure of not more than 0.5 inch of water gauge is available to move air through the air-cleaning device.

Class D. High Resistance, Non-Automatic.—Air-cleaning devices for the air intake of compressors, internal combustion engines, and the like, where a pressure of 1.0 inch or more of water is available to move air through the air-cleaning device.

Air-cleaners may be classified also as follows:

(*A*) *According to principle of operation:*

- (*a*) Air-washers
- (*b*) Viscous air-filters
    - (*1*) Unit type
    - (*2*) Automatic type
- (*c*) Dry air-filters
- (*d*) Electrical precipitators

(*B*) *According to application:*

- (*a*) For central fan systems of ventilation and air-conditioning. Filters of the automatic or semi-automatic type (Fig. 4) are usually recommended, and are installed in a plenum chamber.
- (*b*) For unit ventilators; filters of viscous unit or dry type, installed at the inlet of individual units.
- (*c*) For window installations; self-contained units consisting of fan and filter, usually dry type, adapted to be placed in the ordinary window.
- (*d*) For warm-air furnaces; unit type viscous or dry filters placed in small plenum chamber of warm-air house-heating systems.

AUTOMATIC VISCOUS FILTERS

The construction and design of viscous unit filters have been previously considered in this paper. The automatic viscous filter operates on the same basic principle as the unit viscous filter, except that the filter medium is cleaned and recoated automatically instead of by hand.

The filter medium is usually in the form of an endless curtain (Fig. 5) suspended vertically with its lower portions submerged in a viscous fluid reservoir. The curtain rotates slowly through the oil-bath, thus cleaning and recoating the filter medium simultaneously. This washing and recharging are usually performed intermittently, and are controlled by an electric motor or other rotating device. The motion is so timed as to insure a constant pressure drop, amounting usually to not more than $^3/_8$ of an inch of water when handling an air velocity of 500 cubic feet a minute. This type of equipment is largely used in air-conditioning and general ventilation work as well as in film drying and various processes peculiar to the production of motion pictures. In addition to having a very satisfactory cleaning efficiency it reduces to a minimum the problem of maintenance, as it will operate over long periods without variation in the resistance to air flow and the volume of air delivered.

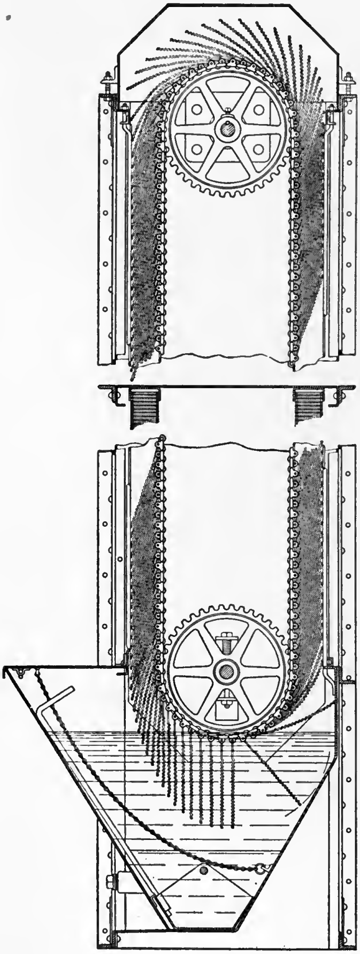

FIG. 5. Sectional view of automatic viscous filter.

DRY AIR-FILTERS

Utilizing felt, cloth, or cellulose, sheets as filter media (Fig. 6) are available in various forms. Due to the low air velocity through the filter medium and the consequent large screen area required with this type of filter, the filter sheet is usually arranged in the form of pockets to bring the face area of the filter unit within convenient dimensions. The resistance to air flow may be controlled either by replacing the inexpensive cellulose sheets (Fig. 7), or, in the case of felt medium, by dry-cleaning or treatment with a vacuum cleaner.

In Los Angeles and San Francisco it is necessary to clean felt filters, on the average, once every 30 days, and manufacturers now recommend dry-cleaning the felts rather than the use of a vacuum cleaner. The necessity for frequent cleaning is due to the accumulation of soot and oil upon the surface of the filter, which stops up the filter surfaces much more quickly than larger dust particles and makes successful vacuum cleaning impracticable.

ELECTRIC PRECIPITATORS

The elimination of smoke and similar atmospheric impurities by electrical discharges was suggested by Hohlfeld in 1824. In 1884 Dr. Karl Moeller in Germany and Sir Oliver Lodge in England, working independently, developed practical constructions utilizing this principle. It was not until 1903, however, that the process was made commercially practical by the development work of Dr. F. G. Cottrell of the University of California.

FIG. 6. Felt filters installed at West Coast studio.

In the Cottrell process the solids are removed by ionization of the air-stream, accomplished by passing the air or gas to be cleaned through a high-voltage field. The latter consists usually of an electrically grounded metal cylinder having a high-tension wire axially suspended through its center. The dust particles are precipitated upon the interior of the cylinder. The cleaning efficiency of the apparatus is high, but the installation is expensive and in general ventilation work there has been some hesitancy to use the high voltages that are necessary.

Some experimental work in electrical precipitation by low voltages and by ionization produced by radioactive materials has been done in this country but such systems are not yet available for commercial applications.

FIG. 7. Airmat filters installed in West Coast studio.

Considerable research is now under way in this country and in England, looking to the commercial application of the principle of thermal precipitation. It has been known for years that if a piece of ice or a hot iron is held under a beam of sunlight the dust motes will disappear. Whether this is another form of electrical precipitation, or whether it acts through other means is uncertain at present.

In England a dust counter has been developed using this principle, and in this country studies have been made as to the possibility of adapting it to commercial air-cleaning.

The relative cleaning efficiency of various filter types is shown in Fig. 8. It should be noted that the figures given represent only the dust-stopping effectiveness of various media against artificial concentrations of Cottrell precipitate (particle sizes mainly smaller than 0.00012 inch in diameter). No consideration is given to air-flow resistance, dust-holding capacity, or other operating characteristics. These ratings should not be confused with operating efficiencies in actual service—the dust concentration, nature of the dust, the relative humidity, and many other factors have a definite bearing upon the results in actual service.

The procedure used in these tests was developed by the U. S. Bureau of Standards. The dust used was fly ash collected with a Cottrell precipitator. The test procedure developed by the U. S. Public Health Service utilizes the Greenburg-Smith impinger and gives very similar results. The test procedure adopted by the American Society of Heating and Ventilating Engineers uses a test-dust consisting of a mixture of powdered lamp-black and coal ash screened to pass a 200-mesh screen. Cleaning efficiencies under this procedure are somewhat higher than by the other two methods.

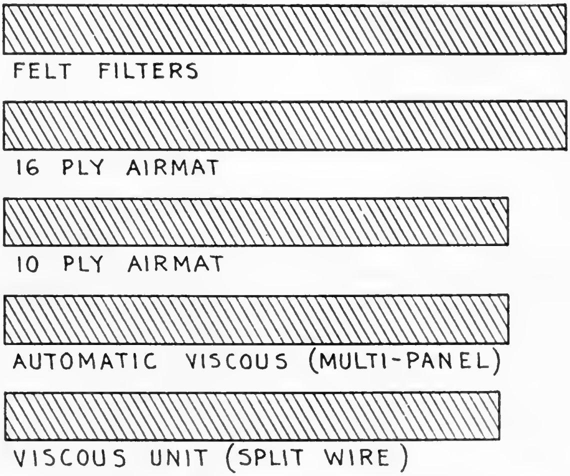

FIG. 8. Comparative test of air-cleaning devices (Bureau of Standards procedure).

While absolutely dust-free air is theoretically possible, it is accomplished only in laboratory experiments and is not yet commercially attainable. Any desired degree of purification can, of course, be achieved, depending upon the requirements; but as a general rule, high-cleaning efficiencies are expensive, not only in first cost but in the cost of operation.

In selecting air-filters for particular applications, various factors should be considered. The dust concentration, the character of the dust, the facilities available for maintenance, and the space available, as well as the first cost and the operating cost, should be considered.

It is difficult to lay down hard and fast rules, but in general the first cost of the "throw-away" type of unit filter is lowest. Next on the basis of first cost would come dry filters of the felt or airmat type. Unit viscous filters of the permanent type are in the same approximate price class and, as might be expected, the automatic viscous filters are more expensive. The cleaning efficiency of the "throw-away" or disposable type, however, while satisfactory for many applications, is not usually as high as that of the other types, and the continual replacement costs may soon add up to more than the price of a permanent unit.

Likewise the decision as to whether the unit or the automatic type should be selected depends upon a number of factors. If the filtered air is to be used for drying operations or for air-conditioning, an automatic filter is desirable. This assures a uniform resistance to air-flow and a consequent uniform air delivery, which are important factors in standardizing drying operations and heat transfers.

If, however, adequate and reliable servicing facilities are available, unit filters may safely be used. The equipment selected should be in the proper relationship to the fan capacity and the allowable resistance. The location and weather protection of the intake should receive adequate consideration, and the location of the filter as regards the heating coils and fans should be carefully worked out.

While it is almost standard practice to locate the filter at the intake side of the fan, there are several considerations which recommend that it be installed at the outlet. This arrangement prevents the possibility of infiltration of uncleaned air through leaks in the ducts, and reduces the transmission of fan noises. It is most important that the duct connections to the filter should provide uniform distribution over the filter surface without eddy currents or dead-air spaces.

MOTION PICTURES AS GOVERNMENT ARCHIVES*

JOHN G. BRADLEY**

Summary.*—Motion pictures with sound recording, which can be said to represent second and third dimensions in recording history, are to be given full status with other Federal Archives. The movement was sponsored by the S. M. P. E. Committee on Preservation of Film in 1930, and one of the early advocates of including motion pictures in the archives of the nation was Mr. Will Hays. The preservation of film was one of the chief problems, and is now being worked out by the Bureau of Standards under the joint sponsorship of the National Archives and the Carnegie Foundation through an original research project under an Advisory Committee set up by the National Research Council. The Committee on Preservation of Film of the S. M. P. E. is assisting in the work. The service to be rendered by such a great national film library has many possibilities.*

Recently I prepared a paper for the Second General Assembly of the Pan American Institute of Geography and History, under the title of "Recording History in Three Dimensions." The three dimensions referred to were (*1*) writing and printing, (*2*) pictures (with special emphasis upon motion pictures), and (*3*) sound recordings. The title of this paper is "Motion Pictures as Government Archives." The two papers are so closely related that a brief summary of the former will serve as an excellent foundation for the latter.

Briefly that summary was this: that there was a time when history was not recorded; when knowledge was handed down orally, by what might be called story-tellers; that when the story was retold, it was told as it was remembered, the lapses being filled in according to the narrator's imagination or purpose; that although the results were frequently beautiful, they were generally inaccurate; that writing, in contrast, was a process of fixation which gave the lie to the story-tellers; that printing gave wings to words and promoted widespread dissemination of knowledge; that pictures (especially motion pictures) added a second dimension, and gave mobility to recorded knowledge; that recorded sound added a third dimension wherein,

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** The National Archives, Washington, D. C.

in addition to reading a man's thoughts in words and seeing his thoughts in pictures, we could actually hear his thoughts and emotions as well; that the benefits of a three-dimensionally recorded history were manifold; and, finally, that our obligation so to record history as a heritage to future generations was apparent.

For such, and other, good reasons The National Archives Act made provision to

> "accept, store, and preserve motion picture films and sound recordings pertaining to and illustrative of historical activities of the United States, and in connection therewith maintain a projecting room for showing such films and reproducing such sound recordings for historical purposes and study."

Authority to record is contained in the words,

> "there is hereby created also a National Historical Publications Commission which shall make plans, estimates, and recommendations for such historical works and collections of sources as seem appropriate for publication and/or otherwise recording at public expense. . . ."

But the history of The National Archives was not quite so brief nor was its realization so apparently easy as indicated by the foregoing statement. It was the result of a struggle extending back a century or more. Men lived their lives, lifted up their voices in its behalf, and died with their dreams still unfulfilled. Printed records continued to accumulate in almost geometric progression, so much so that in 1930 there was a total of over three and a half million cubic feet of executive papers on deposit in the various Federal buildings. Abandoned theaters and churches, old warehouses, attics, and cellars were literally jammed with valuable records, subjected to the ravages of water, dampness, dirt, vermin, and fire. Nearly fifty bills were introduced into Congress before one passed. The authorship of that bill and the credit of its passage belong to the indefatigable Representative Sol Bloom and the friends his leadership commanded. On the Senate side the leadership is accredited to Senator Kenneth McKellar. It would be unfair, however, in this connection not to mention Dr. J. Franklin Jameson of the Library of Congress, who for nearly a quarter of a century gave untiringly of his valuable time and rich talents to this worthy cause. There are many others, but the list is too long to reproduce here.

These early pioneers and agitators for an archives building did not, however, contemplate motion pictures. As far as I am able to learn, the credit for their being regarded as Federal archives belongs first to the Honorable Will Hays, who pressed the matter personally with all the presidents from Harding to Roosevelt, successively.

The Society of Motion Picture Engineers rendered its first service in this respect in 1930, when a "Committee on Film Preservation" was appointed to confer with the architects who had by that time been appointed to design the Archives Building. This committee was composed of W. H. Carson, *Chairman;* H. T. Cowling, *Vice-Chairman;* J. I. Crabtree; A. S. Dickinson; R. Evans; C. L. Gregory; T. Ramsaye; and V. B. Sease. These men performed an excellent service and made a report which, had it been followed, would have rendered our present problems less formidable. But such was not the case, and when this stripling of a young giant, already too big for his breeches, was placed upon our doorstep, we were sorely pressed just how best to cope with him.

We knew he was a bright boy and a good boy with great possibilities, but he had a bad reputation. He had come up through the nickelodeon route and had been the subject of bitter controversy at sewing circles. He also had a reputation for being, shall we say, a little hypersexual, and had not escaped the thunderbolts of the pulpit and the press. The censors had circumscribed him quite effectively and laws were passed to restrict him. In brief, nice little boys were not supposed to play with him. Again, he had a reputation for violence. Upon several occasions he had broken his shackles and smashed up the furniture—in fact, he was acquiring the reputation of being a "killer."

In brief, and to lay aside the figure of speech, our problem might be stated as being three-fold:

(*1*) Giving motion pictures a full-fledged status along with other archives.
(*2*) Providing adequate means to reduce fire hazards.
(*3*) To prolong the life of film material so that it would be comparable to that of other records.

Although the first problem is the least serious, it is not to be overlooked. Motion pictures have not as yet been given full citizenship. There are those who still poke fun at the "movies" or regard them only as a medium of entertainment. For example, the government will appropriate, say, ten million dollars for printing, but it is difficult to get one one-hundredth of that amount for motion pictures.

In regard to the second problem, that of reducing the fire hazard, we are happy to say that we believe we have completely met it to the entire satisfaction of the most critical and nervous. We believe that a major fire in the Archives Building from this source is not only quite remote, but practically impossible if we obtain the equipment we have stipulated.

In the first place, the building is a fireproof building, and probably the most elaborate protective system to be found anywhere in the world has been recommended as a part of its equipment. In the second place, a section of the building, near the roof of the fifth-floor deck, has been isolated for film storage. This section has been further isolated by a concrete vault enclosing eight individual concrete vaults, each of which is vented to the exterior. Half of these vaults will be devoted to acetate or safety film, which offers no great fire problem. In the remaining vaults, where nitrate film is to be stored, we have specified fireproof and explosion-proof cabinets, each to be vented to the exterior.

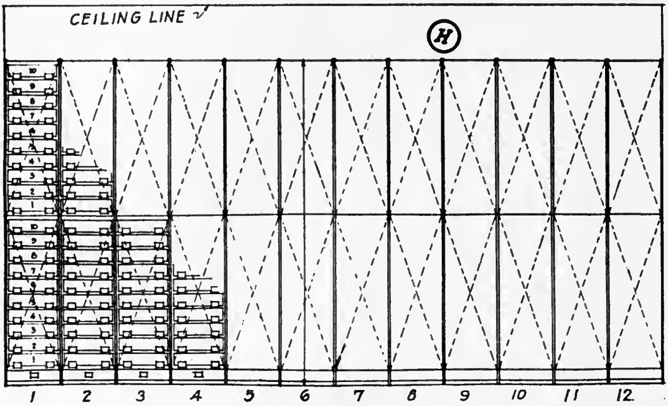

FIG. 1. Typical front elevation to storage cabinets, showing two-section stacks and doors to individual compartments: (*H*) space reserved for horizontal flue to exterior.

But we have gone a step farther; we have proposed to isolate each individual nitrate film in a separate fireproof, explosion-proof, and gas-tight compartment, which, in turn, is vented to the exterior. If one length of film, say, a thousand feet long, should for some reason, of which we can not conceive, catch fire and burn, it would do so without any threat to a neighboring film, and probably no one would know anything about it at the time.

Each of these individual compartments is designed with a gravity fire-trap in the rear, of the floating type, to prevent entrance of a neighboring fire and to permit easy and quick release of any pressure from within, so that explosion of confined gases would be next to impossible. In each of these fire-traps, breather ports have been stipulated to provide easy diffusion, so that any fumes or gases given off by the film will be constantly dissipated, and carried away.

The metal walls of the flues leading to the exterior will be broken by asbestos gaskets to prevent heat conduction from the roof, and floating membranes within the flues have been specified to prevent air convection from the same source. An auxiliary and independent air-conditioning system is being planned for controlling not only the temperature and humidity of these vaults, but the air content as well. Thus all militant influences that might jeopardize the life of a film will be removed.

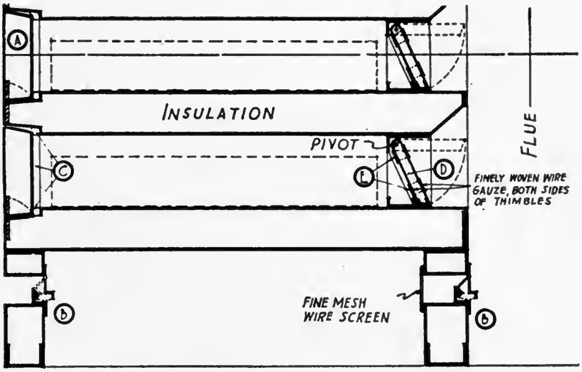

FIG. 2. Vertical cross-section of compartments, and ventilating scheme: (*A*) explosion-proof, gas-tight, hinged door; (*B*) gravity vent traps for air supply to flue; (*C*) pliable fume-tight gasket; (*D*) gravity fire-trap; (*E*) fume diffusion thimbles.

To summarize in reverse order, we shall have controlled air content and controlled temperature and humidity in a fireproof, explosion-proof vented compartment within a fireproof, explosion-proof vented cabinet within a fireproof, explosion-proof vented concrete vault within a vault isolated in a remote section of a fireproof building—all under an elaborate protective system maintained by trained engineers under the strict discipline of the archives administration. We believe that we have taken every reasonable precaution and added a few additional ones as a safety margin. The proposed plan covering storage of nitrate-cellulose film is illustrated by the drawings.

There yet remains, however; the third problem, that of film preservation. When I was asked to organize the Division of Motion Pictures and Sound Recordings, I started out like Diogenes with his lantern, hunting for an honest man. The difference was that I was hunting something else. I went to the manufacturers of raw film stock, I journeyed across the continent to the producers of motion pictures, I came back to the distributors and exchange agencies—everywhere, asking one question: "How can we preserve film five hundred years?" At times I was nearly laughed out of the room, and I confess that by the time my journeys were ended I was content with a hundred-year period. By the end of a century I shall be content to let someone else worry about the problem. I came back a sadder but wiser man; sadder for the reason that my problem was not solved, but wiser in that I had received many valuable suggestions which we are undertaking to collate and enlarge upon.

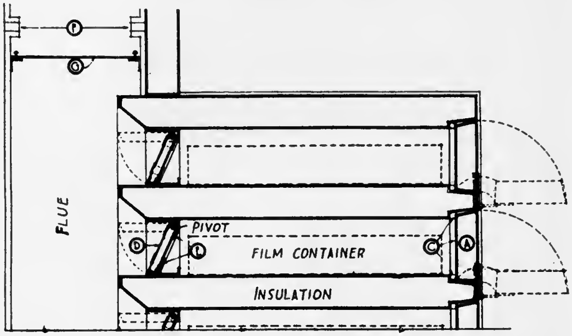

FIG. 3. Vertical cross-section of flue: (*F*) asbestos gaskets to prevent heat conduction from exterior; (*G*) flutter type diaphragm, to prevent passage of air and dirt from exterior, fragile under pressure. For other symbols refer to Fig. 2.

About that time, however, the Carnegie Foundation appropriated a sum of money to be administered by the National Research Council through the Bureau of Standards in a study of film preservation. The study, however, was earmarked for a study of acetate film in connection with microphotography, or the so-called film slide. Then The National Archives transferred additional money to the Bureau of Standards upon the condition that the research project would be expanded to include a study of preservation of nitrate film. Under this joint project, thus provided for and with the generous coöperation of the Bureau of Standards in assigning their equipment and personnel, we have undertaken to find out how to make a film last a hundred years. Not only do we have the able leadership of members of the Bureau of Standards, but we have employed a graduate chemist, Dr. John R. Hill; a laboratory technician (also a chemist), Mr. J. E. Gibson; and a physicist, Mr. Meyer Reiss. The National Research Council has set up an advisory committee to the Bureau of Standards in this connection, composed of the following persons:

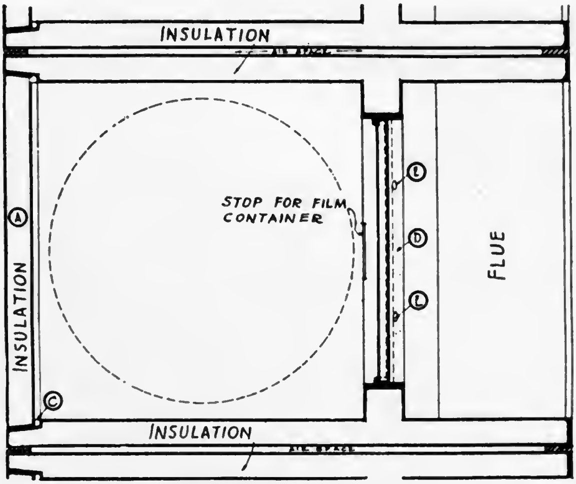

FIG. 4. Horizontal cross-section of film compartment. For symbols see Fig. 2.

DR. H. M. LYDENBERG, Director of the New York Public Library
DR. ROBERT C. BINKLEY, of the Council of Learned Societies
CAPTAIN JOHN G. BRADLEY, of The National Archives
CAPTAIN H. T. COWLING, representing the Society of Motion Picture Engineers
DR. E. K. CARVER, of the Eastman Kodak Company
DR. V. B. SEASE, of the DuPont Film Manufacturing Company

This work has been inaugurated and is going ahead on a full-time schedule. What the results will be we do not know, but we believe that the members of the Society, the members of the Industry, the great libraries of the world, and many others are looking forward to the results eagerly.

In approaching our manifold problems, we have done so with an open mind, and let it be made a matter of record that we shall welcome any suggestions and all coöperation. Although our approach will be inductive, in order to save time we shall accept certain hypotheses as starting points and shall limit our considerations in terms of our apparent needs. Briefly, these are as follows:

(*1*) A study of raw film stock, including base material, emulsion, sensitivity, shrinkage, and flexibility.

(*2*) A study of the processing of film, including fixation of the image, removal of destructive elements, drying, impregnation, *etc.*

(*3*) A study of the handling of film, including a consideration of ideal types of containers, reels, spools, air conditioning, tempering, *etc.* In fact, we propose to run down every reasonable rumor that will give us a better understanding of this complicated problem.

Now comes the reinstatement of the Committee on Preservation of Film, of the S. M. P. E., composed as follows:

JOHN G. BRADLEY, *Chairman*

A. S. DICKINSON
M. E. GILLETTE
J. I. CRABTREE
R. EVANS
C. L. GREGORY
V. B. SEASE
T. RAMSAYE

It is hoped that this Committee will not only carry on original work but that it will coöperate with studies already under way and serve in an advisory capacity to other investigators.

The question arises, what service can this Division render? It is too early to state what our policy will be or to what extent this material will be made available to educational and scientific programs. We have too many immediate problems facing us to see the full length of the road ahead of us. The applications of the material, however, to the various needs are manifold; one or two illustrations will suffice. Looking at history in its broad aspects, languages and dialects are disappearing; we want to record them. Current history, with all its tragedy and romance, should be captured and preserved. In the field of science: the crystallization of metals, the movement of the heart and lungs, the habits of insects, the ravages of soil erosion, the feats of aviation—are all interesting and worthy material for such records. Great men come and go; we propose to record not only their words, but their voices and their appearances as a gift to the generations who will follow us. That is our problem. That is our responsibility and opportunity, which we contemplate with enthusiasm, albeit with not a little humility.

PSYCHOLOGICAL AND DRAMATIC POSSIBILITIES OF HIGH-VOLUME RECORDINGS FOR MUSICAL PICTURES*

V. SCHERTZINGER**

***Summary.**—A brief discussion of the technical and dramatic difficulties encountered in prducing motion pictures containing operatic sequences, and some of the factors that would be involved in producing conplete operas upon the screen.*

Due to the reception of *One Night of Love* and *Love Me Forever,* it is natural that we at Columbia Studios should be the target for innumerable questions regarding the possibilities of putting opera, as opera, upon the screen. First, let me say that neither *One Night of Love* nor *Love Me Forever* can be classed as opera. True, both employed operatic numbers, sung by an operatic star, but opera was not the aim of the productions.

In both pictures opera was employed as a character in, and as a motive for, the story. In *One Night of Love* an operatic career was the ambition of the principal character, played by Grace Moore. It was her goal, and the entire picture was motivated by her ambition. In *Love Me Forever,* opera was again the motive, for the music-loving Italian gambler, played by Carrillo, was ambitious to be a part of the music world he loved. It was the pursuit of this goal which furnished the fundamental basis for the picture.

Our aim was not to produce opera, as opera, but to use it as a motive, as a dramatic part of the story itself. The music was cast to the picture with an eye, and ear, to its dramatic effect and to its fitness to the situation. The *aria* from *Madame Butterfly* used at the finale of *One Night of Love* could not have fitted the situation more perfectly if we had had it written especially for us by the greatest musician in the world. It completely expressed the emotion of the star and paralleled her own situation perfectly in words; its emotional

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* Presented at a meeting of the Technicians' Branch of the Academy of Motion Picture Arts & Sciences, Hollywood, Calif., July 23, 1935. Printed by permission of the Technical Bureau of the Academy.

** Columbia Pictures Corp., Hollywood, Calif.

quality was so well expressed in music that it would have been emotionally impressive had it been sung in a language foreign to the listener. The *aria* was deliberately selected and cast to this sequence for its fitness to the action.

In *Love Me Forever* we employed the music from the first act of *La Boheme* for the same purpose and for the same reasons. In addition to being the most beautiful operatic music ever written, its theme and tempo amplified the emotions of the story. It enhanced, amplified, and pointed out the underlying drama of the situation. Again we cast the music just as we would choose a player for a certain role, to perform a certain piece of business, to add to and build up a dramatic and emotional sequence.

And now the questions: "Why not opera upon the screen in its entirety? Can opera, as opera, be put upon the screen?"

It can; and with greater result, greater appeal, and greater effect than it ever produced upon the stage.

Two years ago—or even a year ago—we should have answered the questions negatively. The mechanical limitations of sound recording would make it impracticable. But today, thanks to the improvements in sound recording equipment and technic and to the increasing skill of the technicians, the screen can do justice to a beautiful voice, or to the full strains of a symphony orchestra. The mechanical difficulties would not hinder us.

Putting full opera upon the screen is possible, but not entirely practicable. It is both possible and practicable as entertainment; it is not as yet practicable from the producer's standpoint.

Even upon the stage, opera has never gained the greatness it deserves, due to the same circumstance that makes it impracticable upon the screen, and that thing is the lack of acting-singing talent. Rarely, indeed, is a great voice coupled with great acting talent; few singers have at the same time great voices and great stage or screen personalities. The recent slump in operatic popularity has not been due to lack of interest in great music, but to the fact that, until very recently, the operatic stage had few great personalities. In the days of Caruso, Scotti, Farrar, Schumann Heink—all great stage personalities—the opera enjoyed great popularity; today its greatest popularity is attained when a Grace Moore or a Lily Pons is singing. Either of these can fill the Metropolitan, or Covent Garden, to overflowing.

But let us assume that these acting-singing personalities are available; that the cast can be filled with accomplished performers having acceptable voices. The question then arises, "Would opera be acceptable in its original languages: in French, German, Italian?" I believe it would.

The radio has helped wonderfully to make the masses appreciate the finest in music. Millions of operagoers attend the performances in the great opera houses, and only a very small percentage of this patronage understands the languages in which the operas are rendered. They attend because of their love of music, and because of the emotional appeal of good music.

Deems Taylor, in his series of radio broadcasts, has proved that it is not necessary to perform the opera in its original language. His translated offerings were very, very successful, and have given an impetus to operatic appreciation that did not exist before. While opera patrons enjoyed the performances when they did not understand the languages, now they are getting far greater enjoyment from them because they can more closely associate the music with the dramatic or emotional situation as it unfolds before them. They can see the reason for the music; they can interpret, through the words, the mood the composer intended the music to portray.

We might say that prior to the English translations it was the music that attracted the patrons; now it is both the music and the story, and many of the operas are excellent stories and plays in themselves. Motion picture producers have recognized them as suitable material: *La Boheme* has been made both into a silent and into a talking picture; *Carmen* has been filmed three or four times; *Faust* and *Madame Butterfly* are powerful stories, sufficient in themselves without any music.

The producer of opera upon the screen would need to be a man of courage; a man willing to put aside the traditions of old and to produce his screen opera with the same amount of ingenuity and modernism as he puts into his screen dramas. He would need to discard the old stage tricks just as he would discard the old stage scenery. He would need to go against the solidified opinion and practice of ages. He would draw a fire of criticism, at first, because he would be doing things that would fly in the very face of operatic tradition.

To illustrate: in every stage performance of *La Boheme,* Rodolfo has always been presented as a bearded man. The programs, posters, librettos— everything connected with the performance—always pictured him as wearing a beard. Why? Merely because beards were in style when *La Boheme* was written. A man was not a man unless he wore a beard. A beard was the mark of masculinity. Rodolfo, when the opera was written, *had* to wear a beard.

We came up against the same moss-bound tradition when we decided to use *La Boheme* in *Love Me Forever.* Rodolfo *must* wear a beard. Who ever heard of a Rodolfo without one? It would not be Rodolfo without a beard; and so forth, and so forth. But we modernized Rodolfo. The screen public would not have accepted a young lover with a beard, regardless of what the opera-wise accepted. We had to portray Rodolfo as a young man—and in America a beard is a mark of age. We shaved him.

Then, too, we changed the character of Rodolfo slightly. We did it deliberately. We changed the characterization to conform to the personality of Michael Bartlett, who was to sing the role. We made the role more light-hearted, more boyish, to take advantage of the talents and abilities, as well as the voice, of this player.

We had to make concessions to the old opera practice, however, for we were not filming *La Boheme* as a story, but as a reproduction of the staging of the opera at the Metropolitan. Naturally we were forced to work within the same physical limitations as would handicap any stage performance of the opera.

Puccini and many of the old composers chose books or plays already produced, and made the musical interpretations of them that became the operas. The music was so composed as to magnify certain bits of action, and the action was played to conform to the musical limitations. As an instance, in the first act of *La Boheme,* Mimi faints from hunger. Rodolfo, reviving her, sprinkles water on her face with his fingers. Four sprinkles—always four—to go with the four emphasizing chords of music that Puccini wrote. The scenes thus treated were overplayed, stilted; Rodolfo had to make these details emphatic, to go with his music. There is no reason why these unimportant bits of interpretation should be retained upon the screen.

The producer of opera upon the screen should not be bound by these crystallized practices of the years. He should be allowed the same latitude, the same freedom of interpretation as he is given in interpreting any screen story. The producers of *Little Women* were not bound by the word of the book, and the producers of any classic are not bound by the now outmoded action, dialog, or speeches of the original author. The screen interpretation of opera should be made as practicable, as interesting, and as beautiful as possible. The producer should not be bound to these old stage tricks, any more than he should be bound to use the drops, side-pieces, tormentors, and flies of the stage. They were necessary upon the stage; they are neither necessary nor natural upon the screen of today.

From a musical standpoint, the world is already acquainted with all opera, whether recognized as opera or not. Popular melodies, hundreds and hundreds of them, are lifted bodily from old operatic scores. I know. I've lifted my share. The music is fundamentally great, and the public acknowledges it. They have heard it in jazz, in popular tunes of the day; have whistled it, sung it—and they love it. The public will accept it as opera because they have already accepted it in the jazzed-up, sugar-coated form, in off-beat tempo, multilated and manhandled, but still beautiful. They are beginning to recognize in radio operatic performances the same strains that have made the so-called popular music so popular.

I hope (and I believe I express the hope of every music lover) that the screen will offer opportunities for the composers of today to express themselves through the medium of the screen. Their expression need not necessarily turn to adapting the old and recognized operas; they should be encouraged to experiment with the screen as a new medium, just as authors and playwrights are encouraged to adapt themselves to writing for the screen. I believe the day is coming when such encouragement will be offered, and when it is, the screen will develop its own school of operatic technic just as it has developed its school of screen technic for authors and playwrights who have turned their talents to picture work. We have the modern composers, such as Stravinsky and Ravel: it remains for us in the motion picture business to encourage such men to put their inspirations upon the screen; to offer them a free hand; to help them to create new and inspired offerings; to pioneer in this new dimension of the screen's possibilities. A little vision, a little encouragement, forebearance, and understanding; a little effort to get away from the well worn channels of present-day practices—and the musical screen will blossom into a far greater thing than we can conceive today.

THE REAL NEED FOR PROJECTION DEPARTMENTS IN THEATER CIRCUITS*

F. H. RICHARDSON**

Summary.—*The benefits to be expected from establishing projection departments in the large theater chains are briefly discussed, and suggestions are made as to the desirable scope of authority to be granted to the heads of such departments. The relation between such a projection department and the individual theaters of the chain is considered, and the economic advantages accruing from the arrangement in the form of more effective projection and in purchasing equipment are discussed.*

More than thirty years ago, when I first entered the field of motion picture projection, I was known as an "operator," which title has since been changed to the more dignified one of "motion picture-sound projectionist." During all that time I have been a close student and observer in the projection field, watching it develop into a profession, the details of which must be handled by careful, intelligent, and capable men, if optimal results are to be attained.

The modern motion picture-sound projectionist must be equipped for his work by considerable study and long, careful training. That many of them are not as yet so equipped in no wise alters the fact that they should be, and must be if the finished product of the motion picture industry is to be placed before the consuming public at its highest value. Moreover, they must be so equipped in order to do the work efficiently, to avoid wasting power, damaging the film or equipment, or allowing it to deteriorate, and thus putting on shows that are not acceptable by the public.

As many of you know, I have travelled widely, visiting great numbers of theaters and addressing more than three hundred gatherings of exhibitors, managers, and projectionists. As a result, unusual opportunity has been afforded me for making observations and forming intelligent opinions as to what is needed in the projection field and what are the real conditions existing therein.

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** New York, N. Y.

It is not in the least astonishing that faults are found in projection equipment and in the work placed before the audiences in very many of our theaters; it is what might be expected, considering the many theater managers who are not too fully equipped with knowledge, and the many who lack almost totally an understanding of either theater management or the requirements for perfection in either screen image or sound results. As a matter of fact, very many theater managers are unable to criticize either the picture or the sound intelligently. It is not pleasant to speak thus, but in the interest of the industry the situation must be realized and emphasized: it is not in the least surprising that under such circumstances projection suffers many ills, and because of those ills the industry suffers huge losses in box-office receipts each year.

When, however, in theaters forming links in a great chain, conditions are found, as I have many times found them, that make directly for low-grade projection, and excellence in screen image and sound impossible, at the same time precluding the attainment of any kind of efficiency, from the economic standpoint, one can not but wonder why the men in the executive positions do not put an end to it.

It is the more astonishing when we consider the fact that such chains of theaters represent huge sums of money, the returns from the investment of which depend in considerable measure upon efficiency of projection and excellence of results.

So far as I have been able to ascertain, there have been and now are only two or three large theater chains in the United States and Canada that have projection departments worthy of the name, or a Director of Projection endowed with authority in any degree commensurate with his title. The truth is that very few directors of projection, or supervisors, as some term it, have any authority at all!

Very few if any such supervisors or directors have any authority over the projectionists employed in the various theaters of the chain, except, perhaps, over those who chance to be located either in or near the "home town." Besides, there are very few directors or supervisors who have any up-to-date knowledge as to the age or condition of the projection equipment in the various theaters of the chain over which they are assumed to have authority. Some supervisors or directors do not know even the makes of all the equipments in their theaters. Practically their whole duty consists in superintending; and in many cases even they themselves make the equipment installations and repairs in the theaters near the home office. Some have no office force at all; others have merely a skeleton force.

It is an absurdity that a great theater chain will not assign so important an activity as projection to a separate department, under a director who is fully authorized to conduct it and all its various details; to select equipment; to standardize equipment for theaters of various classes; to purchase replacement parts, supplying them at cost to the theaters of the chain upon requisition; to discipline the projectionists when necessary; and, in general, to administrate all the projection affairs of the entire chain, acting in conjunction, of course, with the theater managers, but endowed with supreme authority so far as concerns matters pertaining to projection.

Such a course would seem to be good business procedure; yet, it has not been followed, except in a very limited way, by the great theater chains, with one exception. Even in that exception the director, a most able man, does not possess all the authority that he should.

For illustration, I may cite a few facts about a great theater chain which has dissolved and gone out of business, and which I may therefore discuss without fear of injuring anyone. I had occasion to visit many of its widely scattered units, and found that in some of them the conditions were far from the best, so far as equipment and personnel were concerned. In some of the theaters inquiry developed the fact that the projectionists were not only unaware of the name of the supervisor of the chain, but did not know even that a supervisor existed.

Later, I asked the "supervisor" of the chain a few questions. His answers disclosed the fact that he neither had the slightest knowledge of the equipment in some of the theaters, nor had he any records in his office by means of which such information could be gained, except perhaps in the most general way.

It is the purpose of this paper to point out to theater chain executives the utter absurdity of such a situation, and to try very briefly to set forth a few of the most important features of an effective theater chain projection department. Large theater chains own and operate hundreds of thousands of dollars worth of projection equipment and employ a great many projectionists. Surely, then, it is reasonable to suppose that so many men and such high property value should be under the direct supervision of some one responsible officer, and that that officer should head the department of projection. Certainly, theater managers, many of whom, as was pointed out, have little or no definite knowledge of projection, can have no legitimate objection to a director with whom they may upon occasion consult, and who can and will very materially assist in keeping the projection equipment in good condition, besides saving money by purchasing replacement parts in quantities at reduced prices.

In creating a theater chain projection department, the first, most highly important point is to engage as its responsible head a man who has himself been a motion picture projectionist and who is expert in both visual and sound projection. Only such a man can understand the activities of his department from the point of view of the men whose work he is to control and direct.

He must also be well grounded in theory, and have the ability to select the proper kind of assistants and, having engaged them, to evoke their hearty coöperation. Besides all that he must possess the ability to organize and the vision to build up his department to the "pink" of perfection.

Such men are scarce and can not be obtained cheaply; but in a large chain it will pay in the end to secure one, within reason, regardless of cost. No one has criticized projectionists more freely and frankly than I, and no one has so severely condemned those incompetent, irresponsible ones who take little or no interest in their work. However, during my travels I have met many well informed and conscientious projectionists, many of them extremely so. Some I have found who were almost fanatical in their zeal to produce excellent work, and to those men we must give the credit for the advancement of the profession, rather than to the great executives, exhibitors, and theater managers. Such men richly deserve to have over them directors of projection who thoroughly understand all phases of projection and who can and will back them up, when necessary, in procuring those various things and conditions essential to best results.

Considering everything, the appointment of such a director, endowing him with authority and an adequate office force and all necessary equipment, would repay its considerable cost many times over. The results would not only reduce projection overhead costs materially, but would also gradually cause the box-office receipts to grow, by reason of the improvements effected in the picture and the sound.

For best results the director of projection must be given full charge of and authority over the projection affairs of the entire chain of theaters, in the sense that when arguments arise with the managers or others, his decision shall be final. In other words, he must have *real* authority, instead of, as at present, being obliged to act under the direction of some higher-up chain official who, usually admittedly, has no expert knowledge of the best projection procedure.

It is important that the director be provided with a proper office and a staff sufficient to keep his records, attend to necessary correspondence, *etc.* He must be provided with experts who will supervise or make equipment installations, and with such repair men as may seem necessary or advisable.

Among the duties of such a director, he should make a real investigation and practical test of all the present equipment, and of all the many new ones offered to the trade from time to time, to the end that the chain may establish proper standards of equipment for its various classes of theaters. In him should be placed authority to purchase all equipment and repair parts, to be requisitioned by the theaters at cost prices. This would permit mass buying, to some extent at least, and doubtless the purchase of equipment and repair parts at reduced rates. It would tend also to avoid confusion by effecting standards.

Immediately upon organizing such a department, the director should, through the theater managers, obtain from the chief projectionists of the theaters of the chain complete reports of the make, type, and date of installation of every item of projection equipment in the theaters, together with a description of the condition of every part of the equipment that may be subject to deterioration through wear or other causes.

A carefully prepared blank form should be sent to the chief projectionist of each theater of the chain on the first day of each month, with instructions that it be filled out and returned to the director's office as soon as possible. By this means the director will be kept informed regularly and periodically of the condition of the equipment.

The plan has many features of value. It would enable the director to determine which make of equipment stands up best, and furnish him with exact knowledge of the relative worth of different makes of equipment and parts. In many instances it enables him to determine the causes of excessive wearing. Consider intermittent sprockets, for example: the director finds that one theater demands the replacement of intermittent sprockets more often than the others. There are two possible causes, assuming that all the theaters receive sprockets of the same make and type: the aperture tension may be excessive, which is bad for several reasons; or the projectionist may be unwilling to use an intermittent sprocket as long as the projectionists of the other theaters. The director is therefore able to check up and ascertain exactly what the condition is, and remedy whatever may be wrong.

I could point out many instances in which such a system of reports would be of great value. Its most important feature, however, is that it places at the disposal of the projection department complete, up-to-date knowledge of the exact condition of all the equipment for which it is responsible, thus enabling the director to act intelligently with regard to them.

As to the director's authority over all the projectionists in widely scattered theater chain units, that, of course, must be limited. However, it seems rather obvious that benefit would result from the projectionists' knowledge that they must hold themselves, at least in part, responsible to a director of projection endowed with real authority, even to the extent of demanding their discharge if necessary; and that through him they have some protection from possible unjust treatment by the local manager. Moreover, the projectionist who must return detailed monthly reports to an authorized projection department concerning the condition of equipment under his charge, is much more likely to handle his equipment with greater care than he otherwise would.

There are many kinds of theater managers. Some are experts. Some are far from expert, with all degrees between the two extremes. Many treat the projectionists justly, and with kindly consideration. Many do not. It would, then, seem well that in theater chains equipped with such a department as I have attempted very briefly to outline, it might be advisable that local managers be forbidden to discharge projectionists until such proposed action has been approved by the director of projection; and, further, that if the director recommends the discharge of any projectionist for cause, it hall be done.

PRODUCTION PROBLEMS OF THE WRITER AS RELATED TO THE TECHNICIAN*

C. WILSON**

Summary.—*A general discussion of the relations between motion picture writing and engineering technic, together with a brief discussion of the problems facing the writers and the manner of adapting stories to the motion picture technic.*

The writer has no real problems to present to the technicians. As far as I can see, the technical departments of motion picture production are so far ahead of the other branches that it would be highly presumptuous indeed for me to say anything could be construed as criticism in the slightest sense.

We writers sit down and scrawl words on paper—and you technicians calmly accomplish them. After twelve years in Hollywood studios I am still daily astounded by the efficiency of the men who accomplish the physical part of making pictures.

I once served for some months on our local Technical Research Council. I used to leave their meetings in a daze. Far from being able to appreciate the wisdom or advisability of the various discussions, I was not able even to understand *what* was the suggestion under discussion.

Last week I walked out to Stage *14* on our lot where they were to begin shooting a scene from *Mutiny on the Bounty,* and there, occupying the center of a gigantic concrete tank was a piece of machinery resembling what I imagined the main power-house on the planet Mars must look like. Suspended twenty feet in the air was a rowboat containing nineteen men. Behind it was a glass process screen upon which was projected the background. Above it were huge wind machines and tanks containing thousands of gallons of water. Sitting in a chair upon a platform was the director. Beside him was an engineer. At the director's orders the engineer played upon some keys, switches, and levers—and a storm ensued that could never have been

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Metro-Goldwyn-Mayer Studios, Culver City, Calif.

duplicated in any of the vicissitudes of Mother Nature herself. The boat pitched and rocked, the wind howled, rain poured down, and waves broke over the ship with such violence that the safety net beneath the boat more than once proved its advisability. When I realized that all that had been called into being because I had written some words upon a piece of paper, I felt very humble indeed before the brains and energy that could thus literally make words come to life so vividly.

I turned to the production manager of our studio, Joe Cohn, and asked him where this trifling little piece of machinery had come from. Quite carelessly Joe answered, "Oh, we worked it out ourselves—but that's nothing—you ought to see our new apparatus for rain scenes at night, on the back lot." I did not go to see the machinery, which, according to Joe, would dwarf this Gargantuan gadget, because I am a gadgeteer myself and I did not want my heart completely broken.

No, the writer has nothing to suggest to the engineer. He is completely in awe of the engineer because he, as a writer, knows that all he has to do is to write his story without ever being conscious of any limitations due to the fact that the technical department can not engineer them.

I had another astonishing demonstration of technical efficiency when I recently recorded the sound-track for a short subject. It was an emergency rush, and I had no time to prepare the material that I was to record. Did that bother the cutter or the recorder? It certainly did not. We projected the film a dozen times while I, into a microphone, talked freely and extemporaneously on the subject before my eyes. The next morning they projected the film for me with a coherent and intelligent sound-track lecture. The recorded words had been edited as freely as a written article could have been edited and rearranged. Incidentally, I imagine that was the first time such a job had ever been done—and it might be interesting to know that I was immediately offered a job talking over a radio station. I declined it on the grounds that I would not have the same sound engineer and film editor to make me coherent or convincing.

Since I have no problems to present for your solution, perhaps it might be amusing to adopt, for a few minutes, a routine which I employed when I had the honor of addressing your Convention here at the Roosevelt Hotel once before. On that occasion we discussed the then embryonic recording of talking motion pictures. Even with sound in its whining days, I found little to suggest that technicians might do for the writers. So we turned the topic about and had what I thought was a most interesting open forum: does anybody wish to know what the writer might do for the engineer? Can we writers, who blandly put words upon paper for someone else to vivify, do anything to help the technician maintain his wonted efficiency, or to make it simpler or easier to maintain? Do we write too much or too little of description where technical problems are involved? Is our form of script or scenario efficient? Frankly, I think it is not.

DISCUSSION

MR. TASKER: Have you felt that the camera, lights, and things of that sort hamper the writer in producing swift-moving stories such as they like to write?

MR. WILSON: During the first couple of years of sound pictures, the writer's position was discouraging. When he wrote something—and tried to use a certain amount of imagination in doing so—the story as it came out upon the screen was limited by the fixed microphone, the noisy lights—let us go back to that once deadly "microphone." I well remember the time when I first saw the recording of a scene I had written. Before things were satisfactory, we had used up all the microphones in Hollywood and were sending to Burbank for others. But I must say that within the first eighteen months of sound, such problems began to disappear; and for the last eighteen months or two years, I have not been conscious of any restrictions whatsoever. As I said before, I am constantly amazed and sometimes awed by the freedom with which the writer can write, the director can direct, and the actor act anything he pleases—and, thanks to the Technical Department, it comes out upon the screen properly.

MR. TASKER: However, I imagine in some instances, at least, the writer has unconsciously, if not consciously, adapted himself to the technical limitations. The picture is not entirely the technician's beautiful job.

MR. WILSON: Because we were limited in the beginning, we fell into bad habits. I am afraid your early limitations left us a heritage I wish we could discard—a tendency to write our pictures in a too closely restricted frame, whereas the limitations formerly necessitating that now no longer exist. We are still a little "stagy." We are still too prone to have too many characters talking in a room; and while I hold no brief against the stage-play type of motion picture, I think we still limit ourselves unnecessarily. That is our fault, however, not the technicians'. We got into bad habits in the pioneering days, before the engineers could give us sound with the old silent freedom; perhaps we are not as progressive as the engineers—we stick to our bad habits.

MR. GLUNT: Do you write stories to order or prescription, or do you wait until you have an inspiration?

MR. WILSON: The screen writer—or, as we like to call ourselves, the screen playwright, is neither a novelist nor a dramatist, nor a short story writer, nor an essayist. He may be all of those, but when he is writing a motion picture scenario he is a distinct person in a distinct field. Practically every other writer—with the exception of the fiction writer under contract, guaranteed a cash payment in advance to write serials for magazines or novels for a publisher—writes on his own time, on speculation. We get our salary checks every week, and, in all honesty we can not often indulge ourselves to the point of saying, "I don't feel like writing today," or "I haven't the slightest idea how to write—brilliantly—this particular sequence into screen form."

I do not mean to imply that screen writing is a question of a hard-hearted producer's saying, "Write this today and write it magnificently." If he ever does say something like that, it is because an emergency exists: an expensive company is actually shooting—and under such a circumstance it is a pretty good idea for the writer to have his inspirations well oiled and smoothly functioning.

On the whole, I should say that the screen writer's mannerisms are well understood and, on the whole, sympathetically handled. Nevertheless, we *write*. Personally, I get up in the morning and—allowing that I might have done some heavy thinking the night before—I am generally dictating by 10:30 A.M., my own particular preference being that I would rather roughly dictate something and rewrite it later, than wait until I had the thing completely polished in my mind.

Answering the question in a more general way, I should say that probably ninety per cent of the screen playwright's work is done on assignment.

For instance, at present I am working on *The Forty Days of Musa Dagh*, an amazing novel of an Armenian revolt against the Turkish government during the Great War. The producer, Irving Thalberg, asked me whether I had read the novel, and upon learning that I was highly enthusiastic over its picture possibilities, told me to go to work on it. We discussed the book for an hour or so, during which time I learned his views of its various aspects, and then he said, "Knock me off a rough script. This material is so tremendous, so complicated, that we'd better get out immediately a first rough draft of a scenario. Probably when I read the first script I'll only know what we don't want to put upon the screen instead of what we do, but at least we'll start to get this huge panorama under control."

I spent five and a half weeks searching out the essentials of the book and writing them into a scenario with scenes and dialog. Mr. Thalberg read it, said it was "lousy," and we started to rewrite. That is what I am doing at the present time.

Practically all screen writers work on definite assignments. Sometimes we are asked, "Got any ideas for a story for Norma Shearer?" And we might reply, "Yes, I have an idea—a paraphrase of that recent famous lawsuit in New York City where Mrs. Blank sued for the custody of her child from its grandmother."

We might then be told to go ahead and work out the synopsis of such a story, but on the whole, that is an exception to the rule. Mostly, our work is transcribing and adapting desirable material not only to screen form but to the *particular* screen form to which the producer of the picture wants the material converted.

MR. CRABTREE: Do you first make a skeleton, and then supply the details; or do you start right off with the detailed dialog?

MR. WILSON: That depends upon the producer; some prefer skeletons, which we call *treatments*. A treatment might be anything from twenty to one hundred pages long, and relates in more or less narrative fashion how the story will be told upon the screen.

Personally, I do not agree upon the desirability of treatments, and fortunately I have been able most of the time to have a producer who would tell me to write the story out in detailed scenario form. It is my opinion that the most important part of writing is the *writing*. Rupert Hughes once told me that the way to learn to write is *to write*. In other words, while the thinking is very important, of course, it is the execution upon paper that produces dramatic material. Many a great idea has died aborning because it never got beyond the stage of being an idea. Writing is *writing*. One can regard his idea as an achievement only when the words are on paper.

MR. PUFFER: Is the writer of an original story permitted to be the exclusive creator of his brain-child without the muddling interference of a lot of others, of all degrees of ability and experience, from the manager down to other writers who may have a hand in the work?

MR. WILSON: No, unfortunately. Our bosses have got into an unfortunate habit, as we writers believe, of insisting upon too much collaboration in the frenzied search for the highest possible quality in scenarios. On the other hand, standards are very high at the present time. Pictures, particularly important ones, cost too much. *The Forty Days of Musa Dagh* can hardly be produced upon the screen without an investment of seven or eight hundred thousand dollars, at least. The movie has to be pretty good, to say the least, to get back that amount out of its celluloid presentation.

With standards high, with theater gross receipts in many instances a fraction of what they were in 1929, producers too frequently make desperate efforts—and give the writer little chance of being the sole father of his brain-child. I believe that sometimes the extra writers are employed in the hope of adding an extra quality. It is easy to say, "Let's get George to work on this for a couple of days—maybe he'll give us a couple of extra laugh lines." Maybe George will. If he is well selected, he undoubtedly will. But it is true also that the originator of the scenario may be able to dig up a couple of laugh lines if he were given an equal opportunity with George.

I believe in collaboration. I believe in the ability of one mind to strike sparks off another as I believe in the primitive source of fire, flint and steel. But I believe also that collaboration is overdone at the present time. The writer of an original story is occasionally permitted to follow through with its adaptation for the screen, but never exclusively unless he has demonstrated that he has peculiar talents for the particular adaptation.

As an instance, I might mention that our studio recently bought the movie rights to a rather sensational novel, and as a part of the transaction hired the young and brilliant author to come out from New York to work on its adaptation. However, having had no screen writing experience, he was teamed up with an experienced collaborator who knew all about screen technic.

MR. CRABTREE: Can you tell us more of the actual procedure through which your brain goes in order to arrive at a product that will please the producer? Do you first read the book, then re-read, say, one chapter, write that, and then proceed to the next? Or do you get a mental picture of the whole thing, and then go at it?

MR. WILSON: First we get a mental picture of what would be a motion picture of the story—that is, with the understanding that a motion picture is not a novel and not a stage-play. The picture story has a skeleton that outlines its structure as definitely as the bone skeleton outlines the outer form of any animal.

I might say to myself, "Wait a minute! From a motion picture point of view, this book has several endings. We can't use them all upon the screen. Obviously *here* is the big climax, which we should stage near the end of the picture—the solution of which solves our problems and ends our movie. *These* characters are redundant. We'll drop them out. Those three characters we'll combine into one. The whole central part of the book lacks action—merely narrative. We've got to dramatize it." I can add new material to the novel so long as I produce dramatic quality upon the screen. Also, I have to lay it out in sequences. Each sequence or section of a motion picture—I might define a *sequence* as a section of the story that is separated from the other sections by a fade-out or a dissolve—is a miniature play in itself, and must have its own climax and its own curtain for a dramatic ending.

An important decision is as to what things in the story can be thrown away; or, if not entirely thrown away, not actually shown upon the screen, or perhaps told to the audience by one of the characters. In other words, I must isolate the motion picture form of telling the story. Then, as I sit down to write the first part, I must naturally study in detail the part of the book, play, or story that I am converting. Literally, we sometimes tear up a novel while writing a scenario of it.

As to how we actually get our ideas, I insist that it is less inspiration and, as someone has said, more perspiration. Screen writers work hard. We daily face the problem: "By tomorrow, I've got to have, not only an idea, but a good practical and original idea for this sequence. If I don't have a good one, my boss will think I'm crazy or lazy." After all, we are supposed to be trained to having good ideas—practical ones if not great ones, and we must bear the additional burden of producing ideas in the mood that our producer wants. Much of the form of a motion picture scenario, particularly in its final stages, is necessarily molded into the spirit of the producer's desires.

Please do not think that I have any particular grudge against producers. Mostly they are intelligent men, and they are the only ones on the lot who have no alibis. Being the boss, the producer can say, "Writer, I don't like that—but I do like this—we'll do it *this* way." If the final result is bad, the writer has an alibi. But the producer must dominate, and on the whole the situation turns out to be fairly satisfactory. The better producers know definitely what they are talking about most of the time, and, to be perfectly honest, a writer may often justly say to himself, "Well, if *he* says it should be written *that* way, and *I* think it should be written *this* way, I'm probably wrong, because in the past he has proved himself to be right more often than I have."

I speak thus frankly in order to debunk a widespread impression that the writer for the screen has no chance to express himself freely. On the whole, he has a great chance. I know of very few instances when something that I had written that was really good was not accepted with enthusiasm.

MR. CRABTREE: To what extent do you contribute to the art of direction? In other words, do you indicate what the scene should be and how it should be colored, and the like?

MR. WILSON: To be definite, a script is written something like this: I specify the location of the scene—a great hall in the ancient Armenian ancestral castle of our hero. Because I want certain action and I need certain props for the scene, I describe the great eighteen-foot French windows leading out upon the terrace.

I describe my hero coming into that scene, into the home where he was born but which he has not seen for many years. I tell how he is trying to pretend that he doesn't care for his native land or its traditions—that he believes he is at heart a European, not an Asiatic. I describe his actions and his thoughts as he tries to resist the spell of his ancestors. I invent some little piece of "business" that he may use to cover up his emotion, because he does not want his sophisticated French wife to think he is a "softy." In this particular instance I tell how he plays with the rifle he used for shooting rabbits when he was a boy. Finally, he gives in to his emotions, and turns to tell his wife and son of the happy glories of the past.

To put it plainly, the writer is responsible for indicating the key in which the direction is played—and I do not mean to take any credit away from the director because, in the last analysis, it is up to him to make the scene convincing. If he believes it is a good scene, and believes in it, and directs it well, it will be a great scene upon the screen. If the direction is poor, it will be a poor scene, no matter how well it was written. A picture is entirely in the director's hands, but I am glad to say that most directors welcome all the help and advice the writer can give them. They are always encouraging us not to be afraid to overwrite, and are glad to have an extra page even if it tells only the mood or spirit of the scene without any definite action for the characters.

NEW MOTION PICTURE APPARATUS

During the Fall Convention at Washington, D. C., Oct. 21–25, 1935, a symposium on new motion picture apparatus was held, in which various manufacturers of equipment described and demonstrated their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

DEMONSTRATION OF PHOTOGRAPHY BY POLARIZED LIGHT*

J. W. McFARLANE**

The properties and applications of Pola-screens were described in a previous paper by F. Tuttle and the author.[1] Since then considerable interest in the subject has arisen, and further applications have been worked out. The principles of photography by polarized light will be briefly repeated; for a more complete description, reference should be made to the original article.

The Principle of the Pola-Screen.—Pola-screens have the power of polarizing light, and the power of controlling the brightness of light that is polarized. The term "*polarize*" does not refer to color or brightness, both of which we see, but to a third property, which we can not see with the unaided eye. It is concerned with the way a ray of light vibrates. Ordinary light-rays, from a lamp or from the sun, vibrate in *all possible* directions at right angles to the length of the ray. A ray is *polarized* when it vibrates in only one of these directions.

The Pola-screen polarizes rays passing through it, and the single direction of vibration of the ray is in line with the *vibration plane* of the screen. This plane is in line with the engraved line upon the handle of the mount. A ray of light already polarized will pass through the Pola-screen if the vibration of the ray is in line with the vibration plane, but is absorbed more and more as the screen is rotated to 90 degrees from this position, as shown in Fig. 1. At 90 degrees the ray is extinguished. A single screen is useful because of the presence of polarized light in nature, of which there are two sources, which permit many applications for a single Pola-screen.

(*1*) Clear blue sky light, arriving at right angles to the sun's rays, is strongly polarized (Fig. 2).

(*2*) Light reflected from any non-metallic surface at an angle of 32 to 37 degrees to the surface is polarized by the act of reflection (Fig. 3).

Applications of Pola-Screens.—With a Pola-screen at the lens only, requiring an exposure increase of four times, the following effects can be achieved:

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** Eastman Kodak Co., Rochester, N. Y.

(*1*) Photographs can be made obliquely through glass and water to show details beyond, without objectionable surface reflections.

(*2*) Surfaces can be photographed obliquely to show surface detail that would otherwise be obscured by reflections.

(*3*) Bright oblique reflections that interfere with good composition can be subdued.

(These oblique reflection controls do not apply to metallic surfaces.)

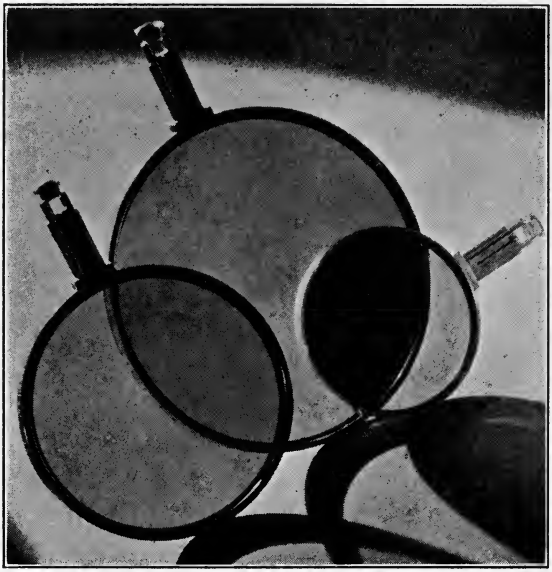


FIG. 1. Commercial sizes of Type *I* Pola-screens: $2^1/_2$, $3^1/_2$, $4^1/_2$ inches; the large screen is passing polarized light; the two others demonstrate the extremes of control of such light, according to angular position. Since oblique reflections are polarized, they can be controlled similarly.

(*4*) When photographing at right angles to the sun's rays, a blue sky can be darkened without affecting the color rendering of the subject photographed. Not only does the Pola-screen provide a filtering action affecting the sky alone, but the effect is variable as well; by merely rotating the screen the sky can be rendered in any shade from quite light to quite dark.

With a Type *I* Pola-screen at the lens and Type *II* Pola-screens at the lights, which arrangement requires an increase of exposure of 16 times or more, the following effects are possible:

(*5*) Trick effects in increasing or decreasing the apparent glossiness of many objects.

(6) Copying and reproducing rough prints, matte prints and oil paintings without trouble from reflections or surface texture.

(7) Unusual lighting and background effects of interest in trick titling and other work.

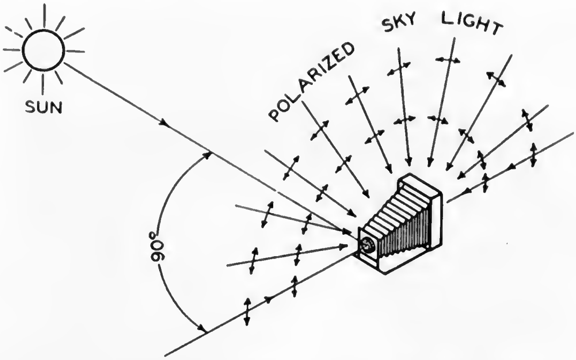


FIG. 2. Clear blue skylight, arriving at right angles to the sun's rays, is polarized. The sky may be darkened without affecting the color rendering of the foreground objects. The strongest effect is attained with the camera axis roughly at right angles to the sun's ray.

The Use of the Indicator Handle.—The indicator handle is a device attached to the rim of the Type *I* Pola-screen. Its purpose is to simplify the angular adjustment of the screen, especially in obtaining dark sky effects. The indicator handle has a line engraved upon it, and a small projection at the outer end of this engraved line parallel to the vibration plane of the screen. To obtain a dark sky effect, the indicator handle is pointed toward the sun. This condition will be realized when the shadow of the projection that was mentioned falls along the engraved line. The handle is also helpful in some cases when dealing with oblique

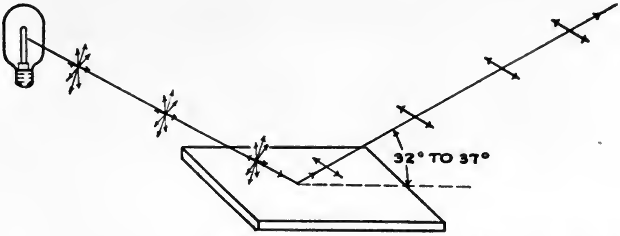


FIG. 3. Ray plane-polarized by reflection. A ray of ordinary, unpolarized light is almost completely polarized when specularly reflected at about 32–37 degrees to any non-metallic surface, such as glass. This permits eliminating oblique reflections from glass and water by a single Pola-screen over the lens.

reflections. When subduing the reflection from a horizontal surface, the indicator handle should be vertical; when the reflection to be subdued is from a vertical surface, such as a glass window, the handle should be horizontal, provided the camera is reasonably level. In all cases, however, the effect can be seen, and where there is any discrepancy between the settings of the indicator handle as described and the appearance in the finder, the cameraman should be guided by the latter.

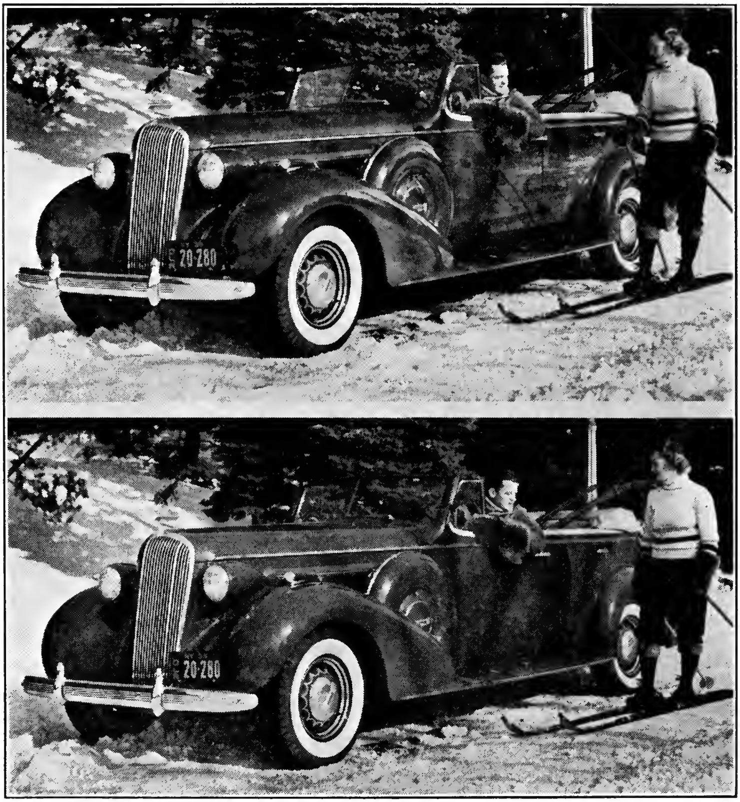


FIG. 4. Motor car photographed in daylight with and without the Pola-screen over the lens, to subdue reflections on the side of the car. Oblique reflections frequently interfere with good composition, producing distracting patterns and objectionable highlights. Reflections form one of the worst problems in photographing motor cars. When the surfaces giving rise to them are oblique to the camera axis, the reflections can be greatly subdued by the Pola-screen at the lens alone.

Demonstration.—The demonstration of photography by polarized light includes two 16-mm. motion pictures: one black-and-white, the other Kodachrome.

These films were made, with one exception, as noted, with a Pola-screen in front of the camera lens, requiring an increase of four times in the exposure.

Typical scenes from this film are as follows: (*1*) Bright reflections from roofs are subdued, to obtain proper contrast against the sky. (*2*) Oblique reflections from the side of a motor car are subdued and then made to reappear, as in Fig. 4. (*3*) Oblique reflections from a motor car window and from store windows are greatly subdued, to show the people and the display inside, as in Fig. 5. The details of various surfaces, floorings, tile, *etc.*, are brought out in a striking manner by subduing the surface reflection, as in Fig. 6. A yellow brick building is photographed against the sky to show the dark sky effect, as in Fig. 7. An oil painting

FIG. 5. Shoe store window photographed in daylight with and without the Pola-screen over the lens, to subdue oblique reflections. The Pola-screen is not effective in photographing a window straight on.

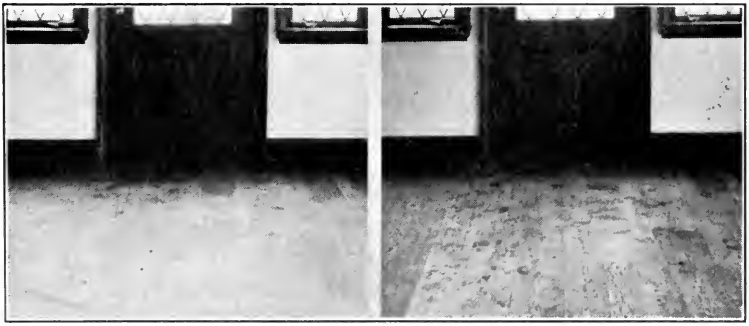
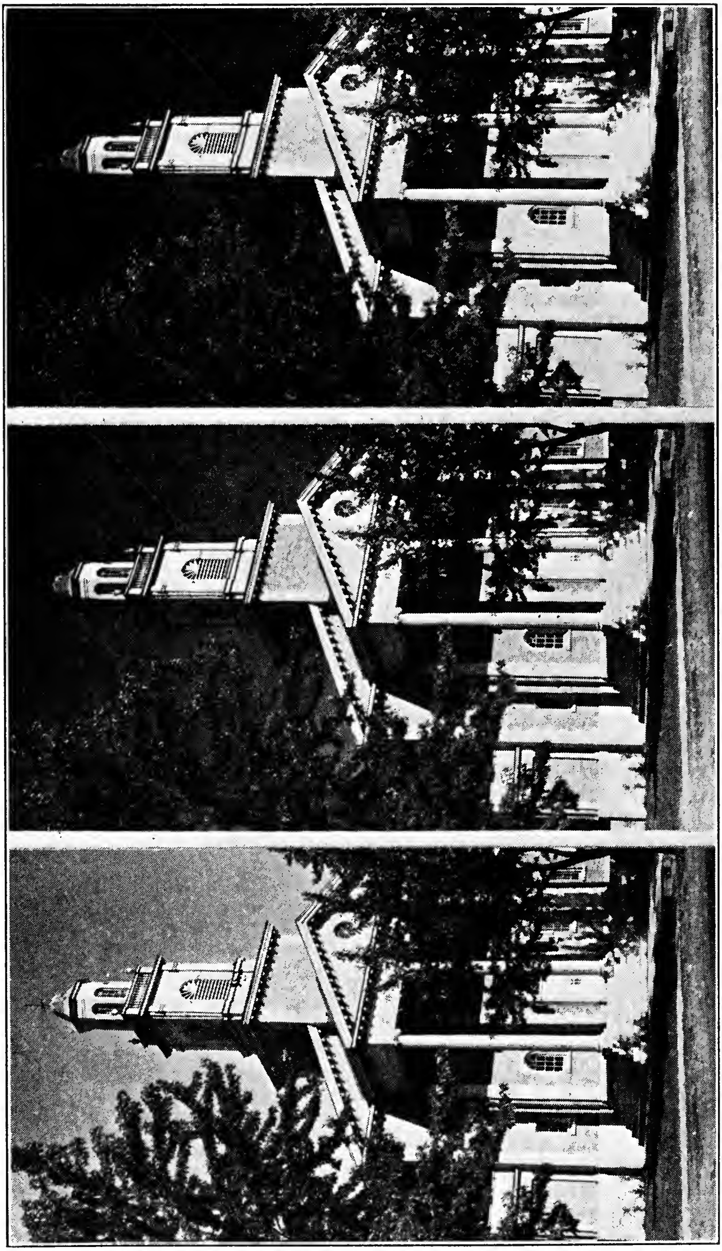


FIG. 6. Oak floor photographed with and without the Pola-screen over the lens, to subdue oblique glare in order to show grain and construction details.



a *b* *c*

Fig. 7. Yellow brick church photographed against the sky; (*a*) no filter, no Pola-screen; (*b*) Pola-screen set for darkest sky (note that the color rendering of the colored brickwork is unaffected); (*c*) Pola-screen set for darkest sky, plus red filter. At the expense of some color distortion due to the red filter, a night effect is attained. Such night-sky effects have been available until now only with infrared sensitive materials, which produce unnaturally light trees and grass.

is photographed to show reflection control with Pola-screens over both lens and lights, as in Fig. 8.

Pola-screens have been used by a number of motion picture photographers since August, 1935, and the results have been very interesting. More applications have been found for them on location than in the studio. The subject is still quite new, and the usefulness of this new photographic tool seems to be limited only by the imagination of the photographer.

FIG. 8. Oil painting photographed with and without the Pola-screen over lens and lights, crossed. The position of the lights was unchanged. Note the absence of speckle from the canvas ribbing and the great improvement in shadow detail.

REFERENCE

[1] TUTTLE, F., AND MCFARLANE, J. W.: "Introduction to the Photographic Possibilities of Polarized Light," *J. Soc. Mot. Pict. Eng.*, **XXV** (July, 1935), No. 1, p. 69.

DISCUSSION

MR. LAND: Probably the only thing completely known about polarizers is that crossing two of them changes the amount of light transmitted through the pair. This knowledge, almost a century old, is the basis of the theories that explain the way that light must vibrate. We are concerned here not with the theories or with the early use of Iceland spar and tourmaline, but with the simple fact that an entirely new material, resembling sheets of celluloid or glass but polarizing light by simple transmission, is now available. It is a transparent sheet, neutral colored, which can transmit, partly block, or completely block light that has previously passed through a similar transparent colorless sheet.

There has been considerable theoretical interest in polarized light, and some of the most outstanding classics of physical literature have been written about the theory and use of it; yet, though polarization is one of the commonest manifestations of light—as common as color—the majority of engineers know little about it; and quite properly, because up to now it has not been commercially available. Now that large areas of polarizer are obtainable, this old property of light can be put to valuable new uses.

The polarizing material consists of a suspension of billions of crystals too small to be seen under the microscope, their polarizing axes all turned in the same direction and each crystal possessing some polarizing power so that the total effect of the thousands of layers of crystals in the sheeting is that of vigorous polarization.

MR. McGUIRE: What is the material of the polarizer?

MR. LAND: Broadly, the principle requires the use of any minute polarizing crystals turned the same way, so small as to render the sheet homogeneous and non-scattering. In particular, one substance that we have used is iodo-quinine sulfate, well known since 1850, but not useful hitherto. One suitable suspending medium is cellulose acetate. We use other crystals and other suspending mediums, but those I have mentioned are good examples of a combination satisfactory for many purposes, and are quite adequate for illustrating the principle.

MR. ROGER: Are the crystals oriented by mechanical means?

MR. LAND: We have used electrical, gravitational, mechanical—all sorts of methods. The particular method chosen is a matter of expediency, refinement, and commercial availability.

THE DEBRIE 16-MM. PROFESSIONAL PROJECTOR*

H. R. KOSSMAN**

For many years the policy of the Debrie Company has been to manufacture motion picture equipment conforming only to the highest professional standards of quality and precision. No deviation from these standards has been allowed in the new 16-mm. sound-film projector. Prior to the introduction of this piece of apparatus, the Company had not been engaged in the manufacture of any type of 16-mm. projector; hence there was no tendency to base the design of a new sound projector upon a production necessity involved in the possible use of existing tools and dies.

The design of the machine has been such as to accomplish the following aims, which have seemed most desirable in a projector using 16-mm. films: simplicity and sturdiness, omission of unnecessary parts, ease of threading and operation, most efficient use of the light-source, and quietness of operation (Fig. 1).

In spite of the apparent simplicity of the film path in the Debrie projector, the reproduction of a constant-frequency record exhibits minimal fluctuation or

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* Presented at the Spring, 1935, Meeting at Washington, D. C.

** Andre Debrie, Inc., New York, N. Y.

waver. This is accomplished by applying the same precise manufacturing methods employed in producing our high-grade professional cameras and laboratory apparatus.

Only two sprockets are used in the machine (Fig. 2), the feed sprocket and the sound sprocket, which latter also feeds the film to the take-up reel. The sprockets are large in diameter, having 16 teeth each. Pressure rollers for holding the film in place upon the sprocket teeth are not used. When threading, the film is simply slipped under fixed rollers, set at the proper distances from the sprocket axis to assure perfect engagement at all times. It is felt that such an arrangement presents less danger of damaging the film.

The intermittent motion of the film is effected by a double claw, which engages two consecutive perforations of the film simultaneously. This distribution of strain upon the film over two perforations is especially important in a 16-mm. sound projector, where the work of moving the film has to be performed entirely from one side. Not only does such an arrangement distribute the wear more evenly, but it also renders the operation of the intermittent more dependable. Even if one perforation of the film should happen to be damaged, the two-claw intermittent would still pass the film dependably through the gate.

The claw movement is so arranged that films made according to either the SMPE standard or the so-called DIN-ICE standard can be projected without the necessity of using a reversing prism, which always entails a loss of light and definition. This permits the use also of standard-printed films for rear projection, as frequently used for advertising work.

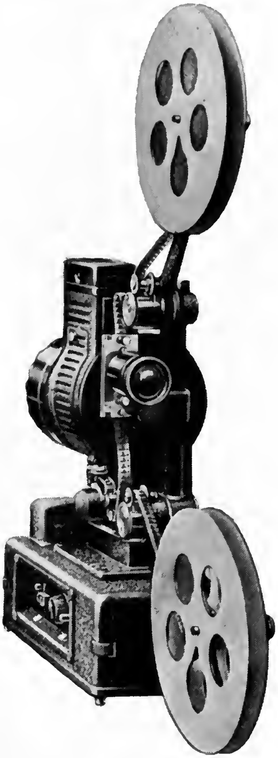


FIG. 1. Showing complete projector with 800-ft. reels, 50-mm. $f/1.7$ projector lens.

After leaving the gate, the film forms a small loop and then passes to the sound drum, where it is held in proper relation to the sound optical systems by a tension device made of special hardened steel (Fig. 3). The sound optical system is rigidly in accurate focus. However, an interesting and unique feature is incorporated here, as the optical system may be quickly adjusted by means of a small lever to focus the slit image upon *either* side of the film. Such an adjustment, it will be seen, permits the use of film with the emulsion either facing the light-source or facing the objective, permitting the sound-track always to be sharply focused with relation to the sound optical system.

After leaving the sound gate, the film passes over a mechanical filter which is so positioned as to afford optimal results with respect to uniformity of motion of the film. The take-up sprocket is located in direct line with the feed sprocket, and both feed and take-up arms are placed in advance of the main mechanism. These arms are long enough to permit the use of 2000-ft. reels. Rewinding the film upon the take-up reel is accomplished by an efficient gear drive and friction clutch of the type that has been in long and successful use in Debrie cameras. Such construction entirely avoids the use of spring belts, with the result that there is no necessity of using reels having unusually large hubs, as is the case when 1600-ft. reels are used with spring belt take-up (Fig. 1). The Debrie take-up construction allows the use of a 1600-ft. reel with a hub small enough to allow it to carry as much as 2000 feet of film.

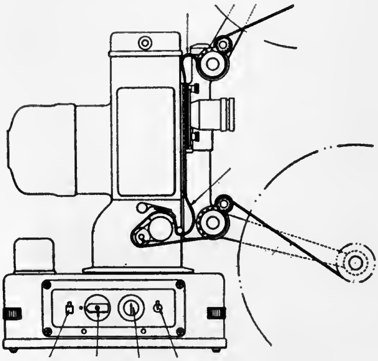
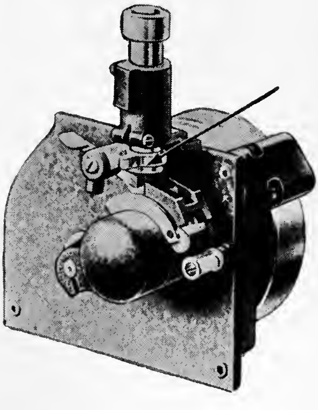


FIG. 2. Showing simplicity of threading: only two sprockets (16-tooth), and no pressure rollers.

The path of the film through the machine is fully channelled and protected, and is so arranged that the film is kept as far as possible from the lamp house and motor, as such parts have a tendency to radiate heat which might dry out the film in constant use.

The entire film-moving mechanism is integral and built as a single unit (Fig. 4). It includes the shutter, the condenser, and the lens assembly. However, the lens mounting swings clear of the aperture, so that cleaning can be efficiently done. All parts of the machine are substantially built. Die-cast parts are incorporated



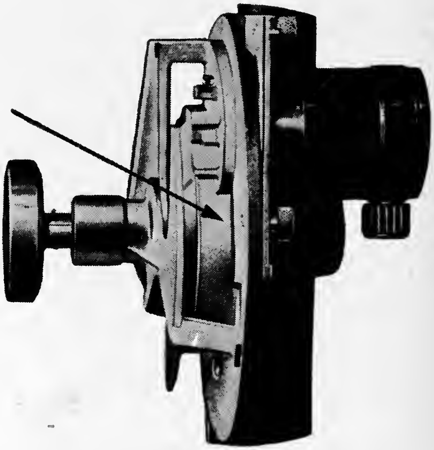


FIG. 3. (*Left*) Sound unit, showing automatic focusing device.
FIG. 4. (*Right*) Casing containing intermittent movement.

where desirable, and no metal stampings are used. The main casting contains the lamp, the motor, and the ventilating fan. The ventilation is unusually efficient, insuring maximal lamp life.

The lamp used is a special 750-watt bulb with offset filament, and burns base up (Fig. 5). Such an arrangement permits using the lamp as a source of light in place of the usual sound exciter lamp. This arrangement provides an unusually great flux of light through the sound optical system; and, as a consequence, the sound slit may be made narrower, thereby improving the quality of the sound and the frequency response. The high temperature of the 750-watt filament causes a lag that virtually eliminates the chance of 60-cycle modulation.

The lamp house and motor housing are die-cast and provided with slots, so that cool air constantly circulates to all working parts of the projector mechanism. The intermittent movement is entirely encased and runs in grease. The optical system is of the direct type and is highly efficient. The large-aperture lens permits projecting a well illuminated picture 12 feet wide at a distance of 90 feet. The driving motor is of the synchronous type, $^1/_{50}$ hp., 110 v. The drive connection between motor and the mechanism is of the friction type, providing protection against emergencies. The ventilating fan is mounted directly upon the motor shaft. Bakelite construction tends to quiet the noise of the fan. The projector is mounted upon a sub-base which contains the pre-amplifier, and also carries the electrical controls, which are arranged on the operating side of the machine, all together and easy of access. Here are located also the amplifier "on-off" switch, the starting switch, the volume control, and the tone control. The starting switch is so arranged that the projector mechanism must come up to speed before the light is turned on.

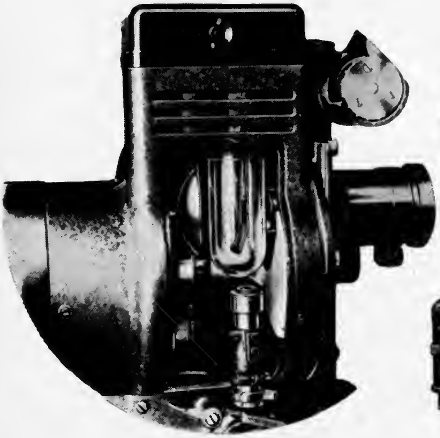


FIG. 5. (*Left*) Lamp house and projection lamp with offset filament, avoiding using a separate lamp as exciter source.
FIG. 6. (*Right*) Projector ready to be placed into carrying case.

The power amplifier is a separate unit, and is transported in a separate case together with the speaker. The object of this arrangement is to provide for connecting the system to other amplifiers, such as those in radio receivers, public address systems, existing 35-mm. amplifying equipment, *etc.* The pre-amplifier contains an output transformer which may be matched with any power amplifier transformer impedance. Such an arrangement makes the Debrie projector extremely flexible, since the power amplification can be chosen to suit any special requirement: the radio can be used in the home; industrial companies that already have 35-mm. installations can use their present amplifiers and wiring; churches and schools can use their public address equipment; small theaters also can use their 35-mm. equipment.

For transportation and storage, the entire equipment is compactly contained in two cases, one of which contains the projector and the other the amplifier and speaker (Fig. 6). The simplified, high-precision construction of the projector mechanism produces a very low level of operating noise and permits it to be operated without a housing or "blimp" case, so that all parts are well cooled and at all times accessible. The weight of the entire equipment is 52 pounds.

DEPUE OPTICAL REDUCTION SOUND PRINTER*

O. B. DEPUE**

When building an optical sound printer it is advantageous to adhere to the general path of the film in the conventional continuous film printer because then the operators will encounter no difficulty in threading and operating the machine (Fig. 1).

The system of lenses and the film movement were suggested by the earlier experiments of A. F. Victor. Both the 35-mm. and the 16-mm. sprockets are on a single shaft, one inside the other. This arrangement appeared to offer the advantages of simplicity of construction and convenience in locating the fairly large flywheel. The two films travel in the same direction and at the proper speeds, with a minimum variation of motion of one film relative to the other. The right-angled prism immediately above the 25-mm. copying lens (Fig. 2) corrects for the otherwise reverse movement of the 16-mm. film.

The 16-mm. film upon which the picture is printed at another time has but one edge perforated, the sound-track occupying the other edge. To simplify the construction and operation the 35-mm. sprocket has but one row of teeth, and the 16-mm. drum is fitted next to it in a position corresponding to the space between the two sides of the 35-mm. sprocket, thus greatly simplifying threading the machine. The 16-mm. film is carried past the printing station not by a sprocket but by an accurately made stainless steel drum of exactly the right size to move the film without slippage. A 24-tooth stainless steel sprocket

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Chicago, Illinois.

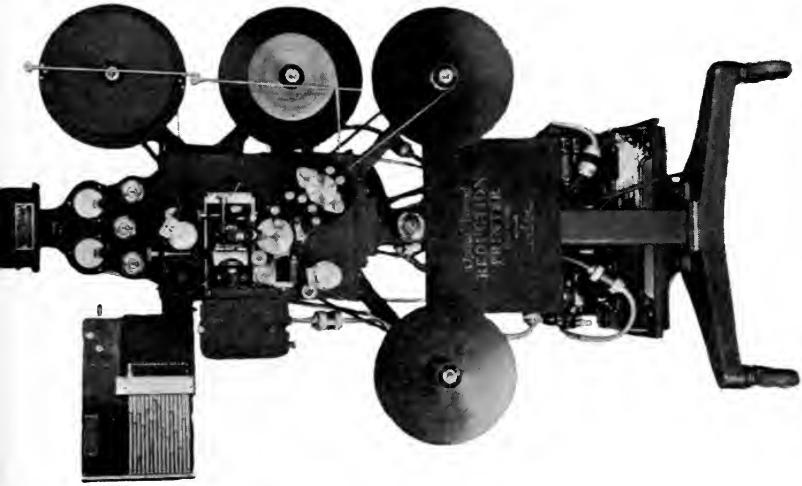

FIG. 1. Depue optical sound reduction printer.

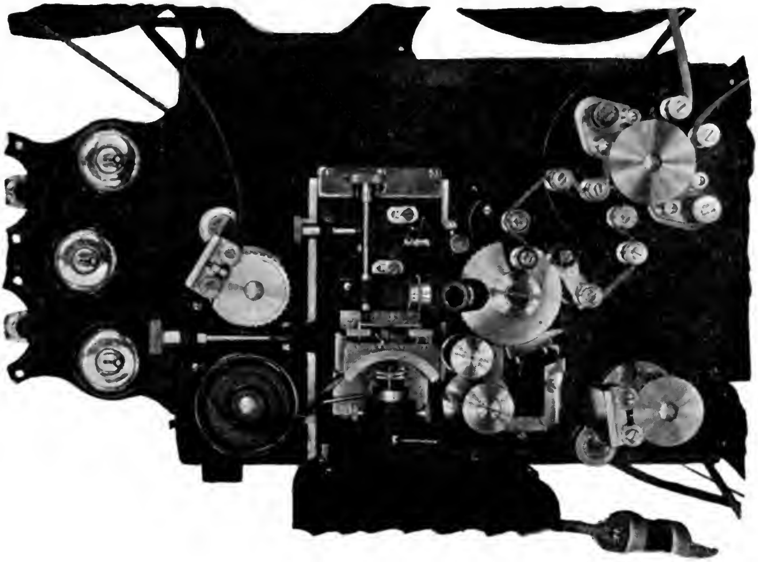

FIG. 2. Close-up of printing gate and sprockets.

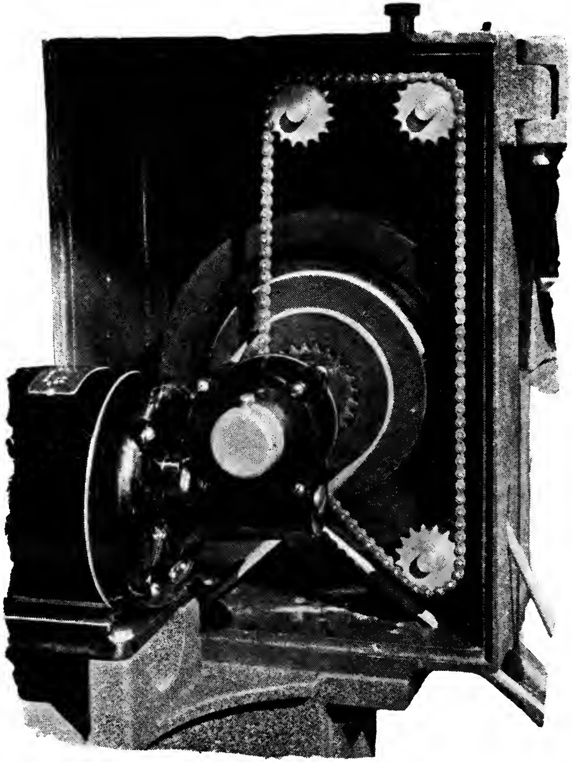

FIG. 3. Rear view of printer, showing drive and fly-wheel.

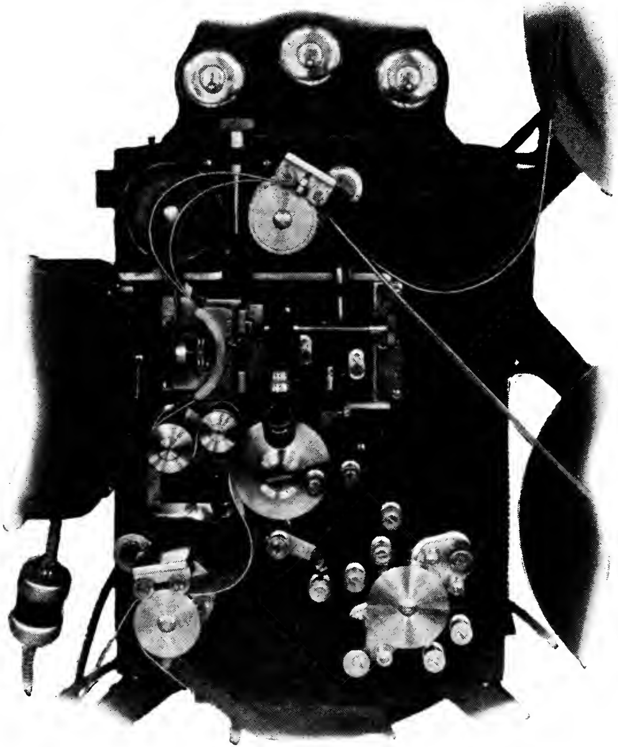

FIG. 4. Close-up of printer threaded for contact printing 35-mm. sound-track.

of very accurate construction is used as feed and take-up sprocket for the 16-mm. film. This feed sprocket is driven by a train of three spur-gears located just inside the housing casting, two of which are of steel and one non-metallic. The center non-metallic gear is so mounted that it can be adjusted to engage the other two gears exactly, thus allowing a minimum of play between sprockets. The minimum number of gears are employed.

Considerable experimenting has shown that by passing the film over several stationary rollers and one tension roller mounted upon an arm immediately below the printing drum (Fig. 2), it is possible to prevent irregularities of film movement caused by contact with sprocket teeth from being communicated to the point of printing.

The same scheme is carried out in the 35-mm. film movement, to a lesser degree. After the film has been fed from the upper 35-mm. sprocket, it follows a gentle curve before entering the curved printing track against which it is held by a shoe. The illuminating beam reaches the negative through an aperture in the curved track. From the negative, light passes to the prism and down to the printing lens. The sound negative then is passed around a pair of rollers before reaching the 48-tooth pulling sprocket. A shoe holds the film gently against the sprocket.

Fig. 3 shows the 12-pound flywheel, which is separated from the motor drive by a rubber disk $^3/_8$ inch thick and 5 inches in diameter. In the disk are six holes, of which three are engaged by pins upon the flywheel and three by pins in a flange on the reduction-gear shaft. This provides a filtered drive to the printing sprockets. The 35-mm. feed and take-up sprockets are driven from a chain sprocket on the reduction-gear shaft through an 8-mm. roller pin chain. Also, the two rewind belts are on the motor side of the filter, and any variation in take-up speeds does not interfere with the smooth running of the printing sprocket. The main bearings are provided with felt linings between bushings which, when soaked with oil, assure lubrication for several days.

It is interesting to note the results of an experiment made by using a very soft spongy rubber filter disk in place of the hard rubber disk. While the sound seemed to be somewhat smoother, a stroboscope showed considerable irregularity of movement of the 35-mm. film at the printing gate, a surprising result in view of the rather heavy flywheel. Undoubtedly this condition would have an unpleasant effect with certain recordings. Consequently, the firmer rubber was used.

In order to provide a satisfactory supply of direct current for the printing lamp, a motor-generator is located upon a bracket at the base of the pedestal. A $^1/_6$-hp., 110-v., a-c. motor drives a 10-v., d-c. generator. The small knob just below the pilot lamp and above the voltmeter and ammeter, controls the generator field-winding resistance, and the exact voltages required can be almost instantly obtained. The motor-generator set is considered superior to a storage-battery as a source of current, especially when the printer is used continuously for long periods of time.

The achromatic condenser system consists of two plano-convex lenses $^7/_8$ inch in diameter. The mechanical slit is adjustable, the width normally being set to 0.0025 inch. A micro objective lens then forms an image of the mechanical slit reduced in size four times. This optical printing slit on the negative therefore is about 0.0005 inch wide.

The copying lens is of 25-mm. (1-inch) focal length. Focusing is accomplished by varying the separation between the two films accurately and by the independent focusing of the lens and the separate movement of the 35-mm. film to and from the prism and copying lens. The optical slit imaging system and the film gate are moved as one unit to insure against disturbing the slit focusing. The lamp is also easily adjusted by a knurled screw at the bottom of the lamp house. It is moved up or down until the light at the printing point is whitest. There are separate adjustments sidewise and back and forth which, once made, need not be given any further attention until a new lamp is installed. Focusing and setting the optical system at the factory assure correct focus and width of sound-track.

In Fig. 4 the printer is shown threaded for contact printing sound-track on 35-mm. film. The two 16-mm. disks are slid along on their respective spindles to allow for 35-mm. rolls. The 35-mm. raw stock is threaded over the sprockets and rollers and through the curved gate with the negative. The printing of standard film through an 0.0005-inch illuminated slit is possible only with the uniform film movement assured by the heavy flywheel. Under the stroboscope, or stop-motion light, the two films show good contact and synchronous movement, both perforations standing exactly in alignment.

The 16-mm. flange and take-up spindles are made to accommodate 1200-foot rolls of positive film.

BOOK REVIEWS

Bluebook of Projection (Sixth Edition). F. H. RICHARDSON. *Quigley Publishing Co.* (New York, N. Y.), 1935, 709 pp. The new sixth edition is essentially a revision and modernization of the earlier fifth edition which appeared in three volumes in 1929. The new edition, complete in one volume, is written in a manner that is informal, understandable, and, as far as possible, non-technical.

Each of the thirty-two chapters is prefaced by a group of questions, the answers to which are found in the text. The first thirteen chapters cover: the fundamental concepts of electricity and electrical engineering; illumination, including source, projection lens, and screen; film; the projector and the projection room. The remaining nineteen chapters cover the various phases of sound reproduction. In contrast to the earlier edition, little space has been given to sound recording, and more space to generalized discussions of the electrical and mechanical fundamentals involved in sound reproducing equipment, as well as its servicing and maintenance. J. STREIFFERT

Agfa Schmal-Film Handbuch. H. LUMMERZHEIM. *Walther Heering Verlag* (Harzburg, Germany), 1935, 118 pp. This book is addressed to the beginner and also to those who have had some amateur or professional experience with 16-mm. film. In the first chapters the dimensional, economic, and safety aspects of using 16-mm. amateur standard film are discussed in contrast with those of 35-mm. film. The familiar matter on cameras, projectors, and handling film is included. Short, separate chapters are devoted to single-frame enlargements and reproduction of sound and color.

The beginner is provided with a clear, detailed description of the processes that he will use. No effort is made to treat the more advanced phases of photoplay production, trick work, or special technics.

The American reader will be interested in the description of Agfa equipment for European use, the chapter on Ozaphane film, and one on German legal regulations affecting "public showing." C. E. IVES

The Ciné-Amateur's Workshop. D. C. Ottley. *Geo. Routledge & Sons, Ltd.* (London), 1935, 138 pp. This little book should delight the heart of the man who likes to "tinker around" and who also is interested in amateur movies. The essential tools necessary for building many accessories are described. Some of the equipment for which detailed working directions are given are: the tripod. the lens hood; an iris diaphragm for "fades"; a mask box; processing apparatus for development; editing equipment, such as a splicer, rewinder, and "cone enlarger" for projecting single frames. The construction of a printer and a titler is described. Several chapters are devoted to the presentation of the finished picture. A model theater for the home is treated in detail. Making sound pictures with the disk recording system is discussed and, finally, storage of films. The book is indexed, and contains a number of interesting photographic illustrations. G. E. MATTHEWS

A Fugue in Cycles and Bels. J. MILLS. *D. Van Nostrand Co.* (New York,

N. Y.), 1935, 269 pp. Although the author's intent was obviously to present his material for the benefit of those whose interest lies mainly in music—and it was for that reason that technical material such as plots and graphs was relegated to a special "Part Four" of the book—there is much of interest and value to anyone whose business it is to deal with sound, by whatever mediums it may be recorded and reproduced.

The four main divisions of the book are: From Pythagorus to Bell; Telephonic Studies of Hearing; An Electrical Future for Music; and Plots and Graphs. The approach is generally historical, and many analogies to everyday experiences are used for the benefit of those who are more musically minded than technical.

The first section discusses the physiological perception of musical tones, simple apparatus for reproducing tones, and musical scales and harmonics. In the second section is a simple discussion of the range of aural perception, loudness, and the translation and transmission of sound. The third section is devoted to the power output of musical instruments, acoustics, noise, and teaching aids. The technical charts, tables, and diagrams concentrated in Part Four constitute a valuable collection of data for motion picture engineers. S. HARRIS

Einführung in die Angewandte Akustik. H. J. VON BRAUNMÜHL AND WALTER WEBER. *S. Hirzel* (Leipzig), 1936, 216 pp. The field of acoustics has in recent years been covered extensively in various German books of the "Handbuch" type. While such treatises are invaluable for reference purposes, they are generally too comprehensive for the reader who wants to gain a general knowledge of the more important developments in the several divisions of modern applied acoustics. It is to this type of reader that this book will appeal particularly.

It begins with a short discussion of the fundamental physical and physiological principles of acoustics. This is followed by chapters dealing with sound measurements, microphones, loud speakers, sound recording, the composition of sound waves of speech and music, sound reproduction, and the acoustics of rooms. The chapter on microphones is especially good, a subject to which one of the authors, Dr. Von Braunmühl has made notable contributions by the development of directional condenser microphones. Less satisfactory is the section on loud speakers, which contains little of the more recent European and American advances. The various methods of recording sound are discussed briefly but rather broadly. Among the optical or semi-optical systems are described such recent developments as the multi-track, variable-width, the push-pull, and the Miller mechanographic methods. The lateral-cut type of phonograph record is discussed in considerable detail, whereas the hill and dale record is mentioned but briefly. Several pages are devoted to a discussion of magnetic recording on steel tape. The chapter on sound reproduction discusses various types of distortion and their effect upon sound quality. The important subject of the acoustics of rooms is treated in a single chapter, but the authors have used excellent judgment in the choice of the material discussed.

An American reader may feel that the European developments have been given undue emphasis, as evidenced by the fact that by far the majority of references are to German sources. This, however, should not detract from the value of the book to the sound technician, as he has readily at hand a number of excellent books in which the American contributions, except those of most recent date, are adequately covered. E. C. WENTE.

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HIGHLIGHTS OF THE SPRING CONVENTION

EDGEWATER BEACH HOTEL, CHICAGO, ILL., APRIL 27-30, 1936

Many industrial motion picture firms and apparatus manufacturers are located in and around Chicago, Ill. It is quite appropriate, therefore, that the Society should hold a convention in Chicago every few years although the acknowledged production centers are Hollywood and New York. Nevertheless, it is gratifying to note that the attendance has increased at each succeeding convention at Chicago. At the Spring, 1936, Convention the total registration was approximately 150 and all sessions were well attended, with the maximum occurring on Wednesday morning when over 250 were present.

The program of papers and presentations, as actually followed at the sessions, was as published on succeeding pages of this issue of the JOURNAL. At noon of the opening day, the usual informal get-together luncheon was held, which was attended by approximately 125 persons. Brief addresses were made by Mr. Loran Gayton, Chief Engineer of the City of Chicago, speaking for Mayor Edward J. Kelley; and Mr. Jack Miller, President and Business Manager of the Exhibitors' Association of Chicago. (A photograph was taken of the gathering, copies of which can be obtained by communicating with the General Office of the Society.)

On the evening of Wednesday, April 29th, the Semi-Annual Banquet and Dance of the Society was held in the Ball Room of the Edgewater Beach Hotel. After suitable introduction by President Tasker, the members were addressed by Professor C. G. Croneis, of the Department of Geology of the University of Chicago, on the subject, "Bringing Movies Down to Earth." The address embodied a description of the application of motion pictures to teaching geology in the classroom, and was accompanied by a demonstration film illustrating the phenomena of volcanic action.

Entertainment provided by the Balaban & Katz Corporation and the Edgewater Beach Hotel concluded the evening.

On the afternoon of Wednesday, April 29th, a conducted tour of inspection was made by a group of over 50 delegates to the Underwriters' Laboratories and the Bell & Howell factory. President A. R. Small of the Underwriters' Laboratories gave a brief, interesting talk about the work of these laboratories prior to the inspection trip. President Tasker responded on behalf of the Society.

PAPERS PROGRAM

One of the interesting features of the Monday program was the paper by M. F. Jameson, T. E. Shea, and P. H. Pierce on "Photoelectric Cells and Their Method of Operation," in which were demonstrated various applications of photoelectric cells to the recording and reproduction of music and speech, as well as the varying characteristics of different types of cells under various forms of illumination.

The paper on "Stereoscopy on the Screen," by L. Lumière, was particularly interesting in view of the recent celebration in Paris and London in honor of Mr. Lumière, one of the pioneers of the motion picture and an Honorary Member of our Society.

Great interest was shown in a short sound x-ray motion picture and the paper prepared by Prof. R. Janker, of the University of Bonn, Bonn, Germany, and released through the courtesy of the Reichstelle für Unterrichtsfilm, the official body of the German Board of Education.

The paper by G. A. Morton on "The Electron-Image Tube" described a means of making infrared pictures visible, the subject of recent developments of the RCA Manufacturing Company under the supervision of Dr. Zworykin.

Considerable interest was aroused in the paper by G. L. Dimmick on the subject of "Increased Resolution in Sound Recording and Printing through the Use of Ultraviolet Light," which had been previously demonstrated at New York before the Atlantic Coast Section of the Society in March.

The papers by C. M. Mugler and D. P. Loye, on Tuesday morning, presented a description of current acoustical practices in the construction and operation of modern sound stages, and were very aptly followed by a study by H. H. Hall of the various classifications and processes of analyzing the content of sound waves.

The symposium on Lighting and Projection on Tuesday afternoon proved of considerable interest. Papers were included on "The Motion Picture Screen as a Lighting Problem" by M. Luckiesh and F. K. Moss, on the characteristics of projection light sources, and on theory, design, and use of photoelectric exposure meters. The report of the Projection Screen Brightness Committee summarized the data given at the symposium held at Washington in October, 1935, suggested a tentative standard of screen brightness, and outlined several problems for future work. The Projection Practice Committee reported on plans for further investigations relative to trade practices and theater conditions.

Motion pictures by the Dufaycolor process were first presented to the Society at the Atlantic City Convention in April, 1934. At the present convention improved examples of this process were demonstrated to the Society, and much interest was shown in the pleasing quality of the color rendition.

A paper on "Projection and Projectors," by A. J. Holman, dealt particularly with the difficulties attending the use of intermittent movements in projectors, and described in detail the single lens wheel, non-intermittent projector developed by the author. This model was considered to be a simplified and improved design compared with the one described before our Society by Mr. Holman in 1930.

A. H. Nuckolls and A. F. Matson described many of the chemical and physical characteristics of motion picture film from the standpoint of care in handling and storage to minimize hazards.

The morning of Thursday, April 30th, was devoted to a symposium on the slide-film, a subject that has assumed a great deal of importance during the past year in connection with visual education and commercial sales activities.

One of the interesting presentations on Thursday afternoon was that by I. R. Smith and C. E. Hamann on the subject of copper oxide rectifiers for supplying current to motion picture arcs. H. F. Olson gave a technical account of the development of a new type of microphone having uni-directional response characteristics. Other papers during the session were devoted to descriptions of recent high-quality sound equipment and new types of amateur 16-mm. apparatus.

APPARATUS EXHIBIT

Although the display was not as large as at some previous Conventions of the Society, it nevertheless included a number of interesting exhibits and aroused considerable interest among those attending the Convention. Some of the equipment included will be described from time to time in succeeding issues of the JOURNAL. The following firms exhibited their new equipment: Ampro Corp., Bausch & Lomb Optical Co., Herman H. DeVry, Inc., Oscar B. Depue, Inc., Eastman Kodak Co., Electro-Acoustics Products Corp., Forest Manufacturing Corp., Hertner Electric Co., Motiograph, Inc., RCA Manufacturing Co., Weston Electrical Instrument Corp.

In addition, there were other companies whose equipment was not formally exhibited upon the exhibition floor, but was used from time to time during the Convention, providing the various facilities for conducting the sessions. These companies are named in the following paragraphs.

ACKNOWLEDGMENT

Credit for the success of the Convention was due largely to the efforts of Mr. W. C. Kunzmann, *Convention Vice-President;* Mr. J. I. Crabtree, *Editorial Vice-President;* Mr. G. E. Matthews, *Chairman* of the Papers Committee; Mr. H. Griffin, in charge of projection; Mr. J. Frank, Jr., in charge of installing the sound equipment; Mr. W. Whitmore, Chairman of the Publicity Committee; Messrs. C. H. Stone, S. A. Lukes, and H. Ellman, of the Local Arrangements Committee; Mr. E. R. Geib, *Chairman* of the Membership Committee; Mrs. C. H. Stone, *hostess,* in charge of the ladies' activities; and Projectionists' Local 110, I.A.T.S.E. Various other members of the Mid-West Section of the Society should be thanked for their efforts and coöperation toward making the Convention a success, among whom should be included Messrs. R. F. Mitchell and O. B. Depue. Thanks are due also to the management of the Underwriters' Laboratories and to the Bell & Howell Company for acting as hosts to the delegates on the tour of inspection held on Wednesday afternoon; and to the Balaban & Katz Corp. and the Edgewater Beach Hotel for providing the entertainment at the Semi-Annual Banquet on Wednesday evening.

The sound and projection equipment used for the technical sessions and during the film programs on Monday and Tuesday evenings was supplied and installed by the RCA Manufacturing Co.; International Projector Corp.; National Carbon Co.; Bausch & Lomb Optical Co.; National Theater Supply Co.; Raven Screen Co.; General Electric Co.; Joe Goldberg, Inc.; Electro-Acoustics Products, Inc.; Bell & Howell Co.; and Herman H. DeVry Corp.

Thanks are due to the Balaban & Katz Corp., and to the managements of the following theaters for courteously supplying passes to the members of the Society during the week of the Convention: Uptown Theater, Granada Theater, Riviera Theater, and Norshore Theater; and to the following firms for supplying films projected during the Monday and Tuesday evening programs: Chicago Film Board of Trade, Metro-Goldwyn-Mayer, Twentieth Century-Fox Film

Corp., Warner Bros., United Artists Corp., RKO Radio Pictures, Universal Pictures Corp., Columbia Pictures, Paramount Pictures, Audio Productions, Inc., and General Motors Corp.

PAPERS PROGRAM

MONDAY, APRIL 27th

10:00 a.m. Business and Technical Session.

Address of Welcome; H. G. Tasker, *President.*

Report of the Convention Committee; W. C. Kunzmann, *Convention Vice-President.*

Report of the Membership Committee; E. R. Geib, *Chairman.*

Report of the Papers Committee; G. E. Matthews, *Chairman.*

Report of the Progress Committee; J. G. Frayne, *Chairman.*

"Organization and Work of the Film Library"; J. E. Abbott, The Museum of Modern Art Film Library, New York, N. Y. (*Demonstration*)

"Stereoscopy on the Screen"; L. Lumière, Paris, France.

12:30 p.m. Informal Get-Together Luncheon.

Addresses by Mr. Loran Gayton, Chief Engineer, City of Chicago; Jack Miller, President and Business Manager, Exhibitors Association of Chicago.

2:00 p.m. Sound Session: S. K. Wolf, *presiding.*

"Photoelectric Cells and Their Method of Operation"; M. F. Jameson, T. E. Shea, and P. H. Pierce, Bell Telephone Laboratories, Inc., New York, N. Y. (*Demonstration*)

"The Technical Basis for X-ray Cinematography"; R. Janker, Surgical Clinic, University of Bonn, Bonn, Germany. (*Demonstration*)

"Harmonic Distortion in Variable-Density Recording"; B. F. Miller, Warner Bros. Pictures Corp., Hollywood, Calif.

"The Electron-Image Tube: A Means of Making Infrared Pictures Visible"; G. A. Morton, RCA Manufacturing Co., Inc., Camden, N. J. (*Demonstration*)

"Increased Resolution in Sound Recording and Printing through the Use of Ultraviolet Light"; G. L. Dimmick, RCA Manufacturing Co., Inc., Camden, N. J. (*Demonstration*)

8:00 p.m. Film Program.

Exhibition of recent outstanding feature and industrial motion pictures.

TUESDAY, APRIL 28th

10:00 a.m. Acoustics and Sound Equipment Session.

"The Acoustic Design of Music Scoring Stages"; C. M. Mugler, Acoustical Engineering Co., Los Angeles, Calif.

"Acoustic Considerations in the Construction and Use of Sound Stages"; D. P. Loye, Electrical Research Products, Inc., Los Angeles, Calif. (*Demonstration*)

"Action Is Needed"; F. H. Richardson, New York, N. Y.

Report of the Standards Committee; E. K. Carver, *Chairman.*

"Recent Improvements in the Variable-Width Recording System"; B. Kreuzer, RCA Manufacturing Co., Inc., New York, N. Y.

"Analysis of Sound Waves"; H. H. Hall, Cruft Laboratory, Harvard University, Cambridge, Mass.

2:00 p.m. Lighting and Projection Symposium: L. A. Jones, ***presiding.***

"The Motion Picture Screen as a Lighting Problem"; M. Luckiesh and F. K. Moss, General Electric Co., Cleveland, Ohio.

"Color Quality of Light from Some Incandescent Lamps"; R. E. Farnham and R. E. Worstell, General Electric Co., Cleveland, Ohio.

"Present Trends in the Application of the Carbon Arc to the Motion Picture Industry"; W. C. Kalb, National Carbon Co., Inc., Cleveland, Ohio.

"Theory, Design, and Use of Photoelectric Exposure Meters"; A. T. Williams, Weston Electrical Instrument Corp., Newark, N. J.

"A 13.6-Mm. Super-High-Intensity Carbon"; D. B. Joy, National Carbon Co., Inc., Fostoria, Ohio.

Report of the Projection Screen Brightness Committee; C. Tuttle, *Chairman.*

Report of the Projection Practice Committee, H. Rubin, *Chairman.*

8:00 p.m. Special Sound Demonstration.

Exhibition of recent outstanding feature pictures and short subjects.

WEDNESDAY, APRIL 29th

10:00 a.m. Laboratory and Projection Session.

Report of the Committee on Preservation of Film; J. G. Bradley, *Chairman.*

"A Film Emulsion for Making Direct Duplicates in a Single Step"; W. Barth and F. Schoeck, Agfa Ansco Corp., Binghamton, N. Y. (*Demonstration*)

"Projection and Projectors"; A. J. Holman, East Orange, N. J.

"Some Properties of Motion Picture Film"; A. H. Nuckolls and A. F. Matson, Underwriters' Laboratories, Chicago, Ill.

Report of the Color Committee; J. A. Ball, *Chairman.*

"Color Prints on a Screen-Film by the Negative-Positive Method"; W. H. Carson, Dufaycolor, Inc., New York, N. Y.

"A Sound Picture Reproducing System for Small Theaters"; G. Puller, Bell Telephone Laboratories, Inc., New York, N. Y.

2:00 p.m. Visits to the Underwriters' Laboratories, Bell & Howell Co., and Wilding Picture Productions, Inc.

7:30 p.m. Semi-Annual Banquet.

Address by Professor C. G. Croneis, Department of Geology, University of Chicago, Chicago, Ill.; "Bringing Movies Down to Earth."

THURSDAY, APRIL 30th

10:00 a.m. Slide-Film Symposium and Non-Theatrical Session: S. K. Wolf, ***presiding.***

"Visual Education and Slide-Films"; J. B. MacHarg, Professor of American History, Lawrence College, Appleton, Wis. (*Demonstration*)

"Slide-Films for Use in the Extension Division of the U. S. Department of Agriculture"; C. H. Hanson, Extension Service, U. S. Department of Agriculture, Washington, D. C. (*Demonstration*)

"Improvements in Slide-Film Projectors"; Miss Marie Witham, Society for Visual Instruction, Chicago, Ill.

"Development of Sound Slide-Film Equipment"; F. Freimann, Electro-Acoustic Products Co., Fort Wayne, Ind. (*Demonstration*)

Report of the Committee on Non-Theatrical Equipment; R. F. Mitchell, *Chairman*.

"The Business Screen—Some Demands Made upon It"; W. F. Kruse, Bell & Howell Co., Chicago, Ill. (*Demonstration*)

2:00 p.m. Apparatus and Equipment Session: S. K. Wolf, ***presiding.***

"Photographic Race-Timing Equipment"; F. Tuttle and C. H. Green, Eastman Kodak Co., Rochester, N. Y.

"Use of Motion Pictures in an Accurate System for Timing and Judging Horse Races"; H. I. Day, New York, N. Y. (*Demonstration*)

"Demonstration of 1000-W. 16-Mm. Filmosound Projector"; R. F. Mitchell and W. L. Herd, Bell & Howell Co., Chicago, Ill.

"The Model *E* Kodascope"; A. E. Schubert and H. C. Wellman, Eastman Kodak Co., Rochester, N. Y.

"Copper Oxide Rectifier for Motion Picture Arc Projection"; (*Part A*) I. R. Smith, Westinghouse Electrical & Manufacturing Co., East Pittsburgh, Pa. (*Part B*) C. E. Hamann, General Electric Co., Bridgeport, Conn.

"A New Monitoring Telephone Receiver"; H. F. Olson, RCA Manufacturing Co., Inc., Camden, N. J.

"A New Rotary Stabilizer Sound Head"; F. J. Loomis and E. W. Reynolds, RCA Manufacturing Co., Inc., Camden, N. J.

"A Uni-Directional Microphone"; H. F. Olson, RCA Manufacturing Co., Inc., Camden, N. J.

"The Magazine Ciné-Kodak"; O. Wittel, Eastman Kodak Co., Rochester, N. Y.

"The Pull-Down Movement"; A. S. Newman, London, England.

SOCIETY ANNOUNCEMENTS

FALL, 1936, CONVENTION

OCTOBER 12-15, INCLUSIVE
ROCHESTER, N. Y.

Arrangements are going forward to make the forthcoming Rochester Convention one of the most successful in recent years, and the Papers Committee is already hard at work collecting an interesting and valuable array of papers and presentations. In respect to papers, the attention of prospective authors is called to the announcement of the Papers Committee at the bottom of the inside front cover of this issue of the JOURNAL. Details of the Convention will be published in the next issue of the JOURNAL.

ATLANTIC COAST SECTION

At a meeting of the Section, held at the Hotel Pennsylvania, New York, N. Y., May 13th, Mr. George Wheelwright, 3rd, presented a paper, accompanied by elaborate demonstrations, describing the properties and uses of the new material, "Polaroid." The material and its photographic uses were described previously in the JOURNAL (July, 1935, and January, 1936). This presentation included a description of other uses of the material besides photographic. A demonstration was given also of stereoscopic 16-mm. motion pictures, both black-and-white and Kodacolor, the members of the audience being supplied with eyeglasses equipped with the polarizing material.

JOURNAL AWARD AND PROGRESS MEDAL

The following regulations pertaining to the Journal Award and the Progress Medal of the Society of Motion Picture Engineers are published in accordance with the provisions for such publication contained therein. Members of the Society who wish to nominate recipients for either or both the Awards should communicate their nominations to the General Office of the Society as promptly as possible.

JOURNAL AWARD

The Journal Award Committee shall consist of five Fellows or Active members of the Society who shall be appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

A cash award ($50, or other sum as may be appropriated by the Board of Governors) shall be made at the Fall Convention of the Society to the author or authors of the most outstanding paper which is originally published in the

JOURNAL of the Society during the preceding calendar year. This Award shall be known as the Journal Award. An appropriate certificate shall be presented to the author or to each of the authors, as the case may be.

A list of five other papers shall also be recommended for honorable mention by the Committee.

A majority vote of the entire Committee shall be required for the election to the Award. Absent members may vote in writing.

The Committee shall be required to make its report to the Board of Governors for ratification at least one month prior to the Fall Meeting of the Society.

These regulations, a list of the names of those who have received the Journal Award, the year of each award, and the titles of the papers shall be published annually in the JOURNAL of the Society. In addition, the list of five papers selected for honorable mention shall be published in the JOURNAL of the Society during the year current with the Award.

The Journal Award Committee for the current year is as follows:

A. C. HARDY, *Chairman*

E. HUSE	G. F. RACKETT
K. F. MORGAN	E. A. WILLIFORD

The Awards in previous years have been as follows:

1934—Peter Andrew Snell, for his paper entitled "An Introduction to the Experimental Study of Visual Fatigue." (*Published May, 1933*)

1935—Loyd Ancile Jones and Julian Hale Webb, for their paper entitled "Reciprocity Law Failure in Photographic Exposure." (*Published September, 1934*)

PROGRESS MEDAL

The Progress Award Committee shall consist of five Fellows or Active members of the Society, who shall be appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

The Progress Medal shall be awarded each year to an individual in recognition of any invention, research or development which, in the opinion of the Committee, shall have resulted in a significant advance in the development of motion picture technology.

Any member of the Society of Motion Picture Engineers may recommend persons deemed worthy of the award. The recommendation in each case shall be in writing and in detail as to the accomplishments which are thought to justify consideration. The recommendation shall be seconded in writing by any two Fellows or Active members of the Society, who shall set forth their knowledge of the accomplishments of the candidate which, in their opinion, justify consideration.

The Committee shall meet during the month of July. Notice of the meeting of the Committee held for the purpose of considering the award of the Progress Medal shall appear in the June issue of the JOURNAL. All proposals shall reach the Chairman not later than June 20th.

A majority vote of the entire Committee shall be required to constitute an award of the Progress Medal. Absent members may vote in writing.

The report of the Committee shall be presented to the Board of Governors for ratification at least one month before the Fall Meeting of the Society.

The recipient of the Progress Medal shall be asked to present a photograph of himself to the Society, and, at the discretion of the Committee, may be asked to prepare a paper for publication in the JOURNAL of the Society.

These regulations, a list of the names of those who have received the medal, the year of each award, and a statement of the reason for the awards shall be published annually in the JOURNAL of the Society.

The Progress Medal Award Committee for the current year is as follows:

A. N. GOLDSMITH, *Chairman*

M. C. BATSEL	C. DREHER
J. I. CRABTREE	J. G. FRAYNE

The 1935 Award was made to Edward Christopher Wente, for his work in the field of sound recording and reproduction (*cf. issue of December, 1935*).

The meeting of the Committee will be held July 9th.

The Society regrets to announce the death of

Clem RIZZO

April 27, 1936

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

AUTHOR AND CLASSIFIED
INDEXES

VOLUME XXVI

JANUARY-JUNE, 1936

AUTHOR INDEX, VOLUME XXVI

JANUARY TO JUNE, 1936

CLASSIFIED INDEX, VOLUME XXVI

JANUARY TO JUNE, 1936

Through the courtesy of the authors, a limited number of copies of

OPTIC PROJECTION

by

SIMON HENRY GAGE

and

HENRY PHELPS GAGE

will be available to members of the Society at the price of fifty cents each, including postage. Address requests, accompanied by remittance, to the General Office of the Society or to the Comstock Publishing Co., Cornell Heights, Ithaca, N. Y.

BACK NUMBERS OF THE TRANSACTIONS AND JOURNALS

Prior to January, 1930, the *Transactions* of the Society were published quarterly. A limited number of these *Transactions* are still available and will be sold at the prices listed below. Those who wish to avail themselves of the opportunity of acquiring them should do so quickly, as the supply will soon be exhausted, especially of the earlier numbers. It will be impossible to obtain them later as they will not be reprinted.

	No.	Price		No.	Price		No.	Price
1920	10	$1.00	1925	21	$1.25	1927	29	$1.25
1921	12	1.00		22	1.25		30	1.25
	13	1.00		23	1.25		32	1.25
1922	14	1.00		24	1.25	1928	33	2.50
	15	1.00	1926	25	1.25		34	2.50
1923	16	2.00		26	1.25		35	2.50
	17	2.00		27	1.25		36	2.50
1924	18	2.00		28	1.25	1929	37	3.00
	19	1.25					38	3.00
	20	1.25						

Beginning January, 1930, the JOURNAL of the Society has been issued monthly, in two volumes per year, of six issues each. Back numbers are available at $1.00 each, a complete yearly issue totalling $12.00. Single copies of the current issue may be obtained for $1.00 each. Orders for back numbers of *Transactions* and JOURNALS should be placed through the General Office of the Society and should be accompanied by check or money-order.